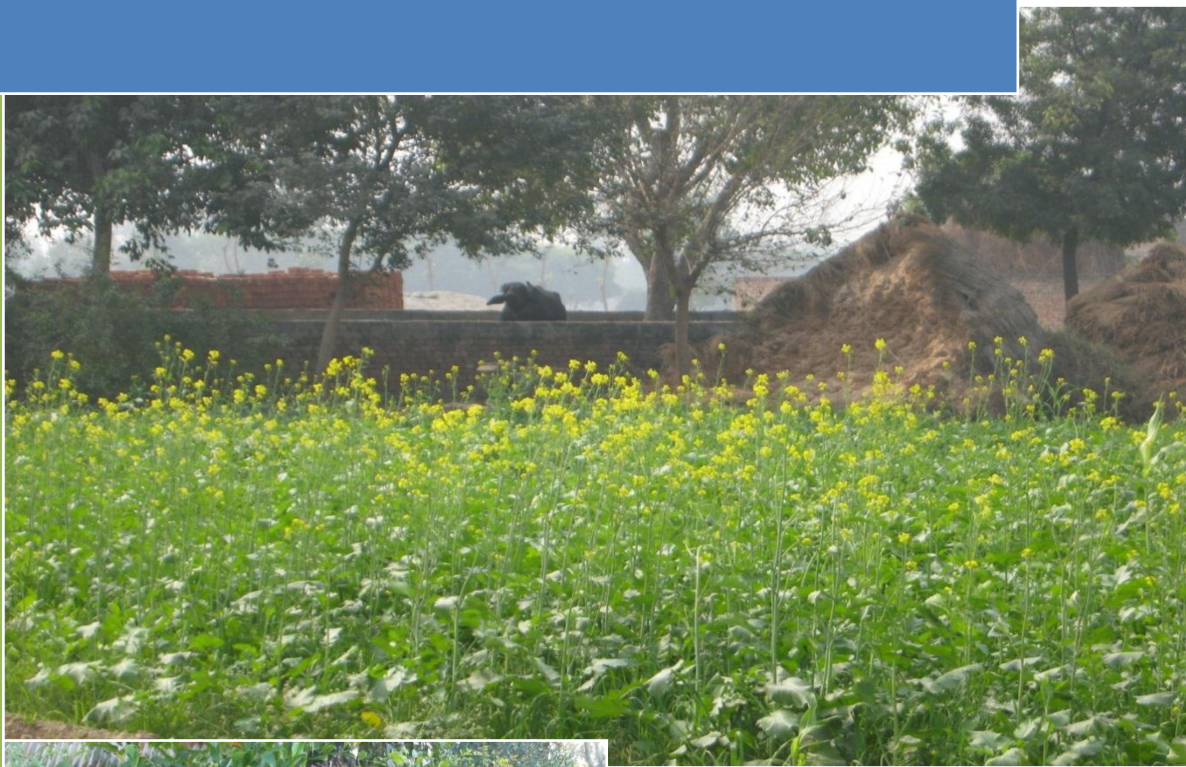
INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
IFPRI
A member of the CGIAR Consortium

APAARI
Asia-Pacific Association of Agricultural Research Institutions

Report on Prioritizing Demand-Driven Agricultural Research for Development in India



Mruthyunjaya
Consultant

Preface and Acknowledgements

Reducing food and nutrition insecurity in Asia requires new solutions to the constraints of: (1) stagnating food productivity and production, (2) unconnected or fragmented food supply chains, and (3) underinvestment in agricultural research and development. Pragmatic short-term solutions are needed that target small-scale farmers who comprise the bulk of food producers in Asia. Simultaneously, the foundations must be established for long-term structural measures that promote the availability, accessibility, and utility of nutritious and safe food, especially for vulnerable groups in Asia.

In an effort to develop both short- and long-term solutions, the Asian Development Bank (ADB) enlisted the International Food Policy Research Institute (IFPRI) under the auspices of a "Regional—Research and Development Technical Assistance (R-RDTA)" agreement in 2011 to provide technical assistance for strategic research on sustainable food and nutrition security in Asia. This ADB R-RDTA addresses important challenges to reducing food and nutrition insecurity in Asia.

One component of this program—characterizing agricultural research for development (AR4D) in South Asia—is addressed in the present document. AR4D is a topic of urgent importance in South Asia. The diversification and intensification of agricultural production throughout the region are among the many issues raised in discussions around South Asia's AR4D agenda at the seminal Global Conference for Agriculture and Rural Development (GCARD) convened in Montpellier in March 2010. Efforts to make further progress on defining and executing a pro-poor and pro-growth AR4D strategy in South Asia requires more evidence on what has worked in the past, where investments are being made at present, and what priorities should be established for future research.

In an effort to support this objective, IFPRI partnered with the Asia-Pacific Association of Agricultural Research Institutions (APAARI) in 2011 to conduct a series of policy dialogues on the prioritization of demand-driven agricultural research for development in South Asia. Dialogues were conducted with a wide range of stakeholders in Bangladesh, India, and Nepal in mid-2012 and this report captures feedback from those dialogues.

This report has benefited greatly from the contributions of Raj Paroda and Bhag Mal of APAARI who were engaged in the entire process. The report has also benefited from insights provided by P. K. Joshi, Mark Rosegrant, and David J. Spielman of IFPRI, as well as technical support from Vartika Singh and Vaishali Dassani of IFPRI and Ram Niwas Yadav of APAARI.

Finally, the report has been made possible by the enthusiastic involvement of the Nepal Agricultural Research Council (NARC), the Bangladesh Agricultural Research Council (BARC), and organizations under the umbrella of the Indian Council for Agricultural Research (ICAR).

In the end, we hope that this exercise will initiate further research and inquiry on these issues and the charge for future agricultural research for development in South Asia will be taken up by researchers from both national and international systems, as well as other key stakeholders.

Contents

List of Abbreviations v

List of Tables vii

List of Figures vii

List of Appendixes vii

Executive Summary viii

1. Introduction 2

1.1 Agriculture, Key to Economic Development 2

1.2 Growth Performance of Agriculture: Some Concerns 2

1.3 Drivers, Opportunities, and Challenges of Growth in Indian Agriculture 8

1.4 Objectives 8

1.5 Methodology 9

1.6 Outline of the Report 9

2. A Critical Review of Key National Policies and Institutions That Influence Agricultural Research for Development Priority Setting, Financing, and Execution 11

2.1 National Policy Formulation 11

2.2 Begging Bowl to Food Self-Sufficiency (Green Revolution): 1950–1970 21

2.3 Beyond the Green Revolution: 1970–1990 21

2.4 Economic Reforms: 1990–2000 22

2.5 Revival of Agriculture: 2000–2011 23

2.6 12th Five-Year Plan: 2012–2017 24

2.7 Overall Picture 25

3. A Critical Review of Structures, Processes, and Issues related to Priority Setting, Financing, and Execution in Agricultural Research for Development 26

3.1 The Enabling Environment for Science: Structural Issues 26

3.2 The Structure of ICAR 27

3.3 The Role and Relations with the Partners 30

3.4 Enabling Environment to Science: Institutional (Process) Issues 37

3.4.1 Priority Setting and Monitoring and Evaluation 37

3.4.2 Administration and Financial Reforms (Organization and Management Reforms) 40

3.4.3 Agricultural Education and Human Resource Development 41

4. A Synthesis of Studies and Views from Stakeholders on Agricultural Research for Development Priority Setting, Financing, and Execution 49

4.1 Key Areas Where Agricultural Research Is Proposed 53

4.2 Agricultural Research Prioritization: The Way Forward 53

5. An Analysis of Potential New Technologies 55

5.1 Nanotechnologies 56

5.2 Biotechnology 57

5.3 Advanced Processing and Packaging Technologies 58

5.4 Resource Conservation Technologies 59

5.5 Information and Communication Technology and Remote Sensing 59

5.6 Biorisk Management 59

5.7 Mechanical Technologies 60

6. A Strategic Plan for Enhancing Agricultural Research for Development 61

6.1 Priority Proposals 61

6.2 Research Priorities 63

6.3 Structural and Institutional Change Priorities 64

6.3.1 Structural Change Priorities 64

6.3.2 Institutional (Process) Change Priorities 65

6.4 Funding Priorities 67

6.5 Technology Delivery Priorities 68

7. Summing Up 69

List of Abbreviations

ADB	Asian Development Bank
AICRP	All India Coordinated Research Project
APAARI	Asia Pacific Association of Agricultural Research Institutions
AR4D	agricultural research for development
ASRB	Agricultural Scientists Recruitment Board
ATMA	Agricultural Technology Management Agency
CGIAR	Consultative Group on International Agricultural Research
CSIR	Council of Scientific and Industrial Research
DARE	Department of Agricultural Research and Education
DKMA	Directorate of Knowledge Management in Agriculture
EAP	externally aided project
FAO	Food and Agricultural Organization of the United Nations
FYP	Five-Year Plan
GCARD	Global Conference on Agricultural Research for Development
GDP	gross domestic product
GFAR	Global Forum for Agricultural Research
GM	genetically modified
GMO	genetically modified organism
HKA	Haryana Kissan Ayog
HRD	human resource development
IAMR	Institute of Applied Manpower Research
IARI	Indian Agriculture Research Institute
ICAR	Indian Council of Agricultural Research
ICRISAT	International Crops Research Institute for Semi-Arid Tropics
ICT	information and communication technology
IFAD	International Fund for Agricultural Development
IIVR	Indian Institute of Vegetable Research
INM	integrated nutrient management
INR	Indian rupee
IPM	integrated pest management
IPR	intellectual property rights
KVK	Krishi Vigyan Kendra
M&E	Monitoring and Evaluation
MIS	Management Information System
NAARM	National Academy of Agricultural Research Management
NAAS	National Academy of Agricultural Sciences
NAIP	National Agricultural Innovation Project
NAP	National Agricultural Policy
NARI	National Agricultural Research Institute
NARP	National Agricultural Research Project
NARS	National Agricultural Research system
NATP	National Agricultural Technology Project
NCAP	National Center for Agricultural Economics & Policy Research
NFBSFARA	National Fund for Basic, Strategic, and Frontier Application Research in Agriculture
NPF	National Policy for Farmers
NGO	Nongovernmental Organization
NRM	National Resource Management
NRCPB	National Research Center on Plant Biotechnology

O&M	Organization and Management
ODI	Overseas Development Institute
PHM	Postharvest Management
PME	Priority setting, monitoring and evaluation
PPP	Public/private–sector partnership
R&D	Research and Development
SAARC	South Asia Association for Regional Cooperation
SAU	State Agricultural University
TNAU	Tamil Nadu Agricultural University
UNDP	United Nations Development Programme
USD	United States dollar
WTO	World Trade Organization

List of Tables

1.1 All India average annual growth rates of area, production, and yield of principal crops (%)
2.1 Policy agenda and analysis of agricultural research for development
2.2 Evolution of public agricultural research and development institutions in India
4.1 Shift in commodity and commodity group research priorities in agriculture and allied sectors in India as reflected in research studies, 1995–2010
6.1 Priorities for agricultural research for development in India

List of Figures

1.1 Growth rates: GDP (overall) and GDP (agriculture and allied sectors)
1.2 Comparative performance of growth of GDP and agricultural GDP
1.3 Average annual growth rate (%) of gross state domestic product from agriculture and allied sectors, 1994/95 to 1999/2000
1.4 Average annual growth rate (%) of gross state domestic product from agriculture and allied sectors, 2001/01 to 2008/09
1.5 Average size (ha) of operational holdings (for all size groups)
1.6 Composition (%) of output of Agriculture and Allied Sectors, T.E. 1990/91 and T.E. 2009/10
3.1 Organizational chart of the Indian Council of Agricultural Research (ICAR) and the Department of Agricultural Research and Education (DARE)
3.2 A framework for technology development and delivery
3.3 Schematic representation of convergence between the micro-and macrolevel priority setting

List of Appendixes

1. List of ICAR/DARE Institutions
2. List of Agricultural Universities
3. Agricultural Research Priorities by Sector and Themes
4. List of Field Trails of Genetically Modified Food Crops Being Conducted by Public Research Institutions
5. List of Field Trails of Genetically Modified Food Crops Being Conducted by Private Companies and Research Institutions

Executive Summary

India has shown an impressive economic growth of about 8 percent per year in the last decade. But the coexistence of impressive growth with widespread poverty and hunger is a real worry and a serious challenge. It is attributed to the lagging and highly volatile growth rate in agriculture, a dominant sector of the Indian economy. Agriculture is the key to economic development of India.

The growth in the agricultural sector is highly unstable and has not exceeded the target growth rate of 4 percent per year. The higher investment in the Five-Year Plans in and for agriculture by the government, particularly after 2004, has not yielded commensurate returns. The agricultural input, service, and supply delivery system is clogged. Agriculture therefore needs serious special attention, more than it has received thus far, particularly in the context of emerging complex challenges of climate change, energy crisis, global economic shocks, and so on.

To boost agricultural growth, a sharp increase in productivity in smallholder farming, which dominates Indian farming, is vital. For this, promoting innovation through science and technology is inevitable. Fully realizing this, the Global Conference on Agricultural Research for Development has deliberated the issues of intensification and diversification of agriculture and recommended collecting new evidence and defining a pro-poor and pro-growth agricultural research for development (AR4D) strategy. The present exercise, with the support of the Asian Development Bank (ADB), is planning to focus on prioritizing agricultural research investments for India to assess innovative funding mechanisms and to refine the agricultural research agenda and innovative AR4D delivery.

This report provides a critical review of key Indian policies and institutions that explicitly influence AR4D priority setting, financing, and execution. The results of this exhaustive review spanning five different periods since independence (1950s) broadly indicate that the country and its National Agricultural Research System (NARS) were quite responsive to the changing economic contexts during different periods, though the country never exceeded the growth target in agriculture and other key parameters. The report duly acknowledges that this is not an average achievement, though it does state that India could have done much better. The research system has also made several efforts, but the results and impacts are not commensurate with the efforts made, as repeatedly revealed by several reviews on the Indian Council of Agricultural Research (ICAR). Why efforts could not lead to expected results should cause everyone to review the structures, processes, funding mechanisms and technology delivery system that form the enabling environment for science to manifest into maximum societal welfare.

The Indian NARS is one of the largest around the globe and has a very elaborate, widespread, complex structure with very exhaustive processes. The size, spread, diversity, and complexity of NARS, which were once considered as strengths, over the years have become sources of stress. They have been designed and evolved over time with the hope of contributing to successful execution of science. But, as stated in the report, they have become hurdles to attaining higher efficiency and delivery of expected output. On account of these, the roles of and relations between ICAR, state agricultural universities (SAUs), government, the private sector, nongovernmental organizations (NGOs), and so on often create stress points that adversely affect performance. In this context, a framework for technology development and delivery is suggested to optimize synergy among diverse partners and align processes to contribute to better performance. The processes relating to the best practices of priority setting, monitoring, and evaluation (PME); administration and finance; human resource development; incentives and awards; communication and publicity; and international cooperation are analyzed; and how to institutionalize them within the system is indicated. The funding to AR4D is not only inadequate but also with inflexible bureaucratic rules and procedures and limited innovative funding mechanisms. Some innovative funding options are explored, particularly under externally aided projects supported by the World Bank. In fact, the innovative features of the ongoing National Agricultural Innovation Project are noted to highlight new thinking in project formulation, implementation, and uptake.

This report prioritizes research by commodities, commodity groups, and resource management areas with subpriorities and priorities relating to structural, institutional, funding, and technology delivery. The research is proposed using the accumulated information, knowledge from credible research sources, quantitative estimates, and elaborate stakeholder consultations, including a specially convened country dialogue meeting on July 2, 2012. Defining and identifying research priorities is important and should continue, but how these priorities will be effectively used to design the research and development programs should be given due attention. Presently, no explicit indications and mechanisms of use of these identified priorities are seen in formulating agriculture research and development programs, including the Five-Year Plan (FYP) that just began (2012–2017). This may happen by chance but not by design.

This report lists several advances in new technologies that have unlimited potential to contribute to technological breakthroughs in future. In fact, after examining some success stories of these technologies, it appears that they will be the major source of productivity growth in the coming years. But, for NARS to benefit from them to the maximum potential, it has to do business differently. Appropriate structures, processes, and funding need to be designed, established, and implemented. The delivery mechanism of the technologies and the goods and services produced from them require an entirely different approach and thus need special attention. Extensive engagement of the private sector in harnessing the potential of new technologies becomes very important, and many more progressive steps will be needed soon.

The end of the report outlines a strategic plan for improved research prioritization, expanded sources and mechanisms of funding and investments, and an innovative delivery and dissemination system of AR4D. While suggesting changes, the report keeps in view the existing structure, organizational culture, managerial and financial norms and procedures, innovative and bold policy initiatives, political economy factors, and monitoring and evaluation culture and practices, because these decide the pace and pattern of performance of the system and sector as suggested. The strategic plan spells out priority research proposals to be complemented with priority proposals on structural, process, funding, and technology delivery changes. As a part of the strategic plan, the top 10 priorities are also identified for future AR4D in India, which focus on the most important aspects across research priorities and other priorities relating to structure, process, funding, and technology delivery. The top 10 priorities are as follows:

1. Ensure functional autonomy to ICAR and its institutes through reducing bureaucracy and by framing rules and procedures with sufficient powers decentralized down the line (refer to Sections 3.1 and 6.2).
2. Introspect, review, and avoid institutional and program proliferation in ICAR through integration, amalgamation, rationalization, consolidation, and even possibly downsizing if necessary. ICAR should function as a lean, thin, think-tank, brain-trust organization with a

focus on policymaking, visioning, and national–regional–global collaboration, coordination, and convergence (refer to Sections 3.1 and 6.2).

3. Intensify multidisciplinary research with a farming system perspective oriented toward small farmers and women and focusing on harsh ecologies; use a consortium mode involving the private sector and all other research partners on commodities (rice, wheat, maize, pulses, and milk), commodity groups (cereals and staple cereals, horticulture, livestock including fishery, and small livestock), resource management (natural resource management including adaptation to climate change and genetics resource management), and transboundary diseases (refer to Section 6.1).
4. Strengthen translational research and technology management capacity for patenting and scaling out innovations with adequate state-of-the-art facilities and skilled manpower to quickly convert technology breakthroughs to benefit farmers and the industry (refer to Sections 5.2 and 6.3).
5. Strengthen and reorient the agricultural education system, based on the review of more than 50 years of experience of the land-grant model of education and on the emerging and future needs and second-generation problems of agricultural education. This can be done through liberal funding strict quality control, and policy support to establish state-of-the-art facilities and upgrade all agricultural universities and state agricultural universities as centers of excellence (refer to Sections 3.1, 3.2, and 6.3).
6. Strengthen and forge the functional relationship for higher convergence of the frontline extension system (Krishi Vigyan Kendras) with all development programs relating to agriculture and allied sectors, including Agricultural Technology Management Agencies. This includes adequate manpower trained in subjects of agriculture and allied sectors, including modern information and communication technologies (ICTs), and the necessary mobility and electronic connectivity to reach inaccessible areas and farmers to provide knowledge input with and adequate and effective input and service delivery system (refer to Sections 3.1 and 6.6).
7. Increase investment in AR4D from the present 0.5 percent agricultural gross domestic product to at least 1 percent in the 12th FYP, 1.5 percent in the 13th FYP, and 2–3 percent subsequently. Maintain the needed balance between agriculture and allied sectors while allocating resources (refer to Sections 3.3 and 6.5).
8. Strengthen human resource development nationally and internationally by liberal funding and a progressive training policy focusing on planning, deputation, and proper utilization of trained human resources (refer to Sections 3.2 and 6.4).
9. Strengthen research on secondary agriculture in and around rural areas covering rural storage, primary processing, value addition, low-cost packaging, grading and standardization, basic awareness about quality testing and safety standards, rural energy (biogas, wind energy, solar energy) management, small-farm mechanization, precision farming, polyhouse production, and all other agricultural engineering aspects involving self-help groups, producer companies, cooperatives, and other local initiatives (refer to Sections 5.1.3, 5.1.6, and 6.1).
10. Strengthen soft skills of agricultural researchers in research policy, long-term planning, visioning, socioeconomics, agribusiness management and policy, advanced computing, use of ICTs, PME, intellectual property rights, participatory research, research documentation, communication, policy dialogue, and publicity to improve implementation of programs, systemwide impact, and increased visibility and credibility of NARS (refer to Sections 3.2, 3.3, 6.4, 6.5, and 6.6).

The first two priorities relate to overcoming institutional deficiencies of less autonomy, insufficient decentralization, large size, wide spread, and overdiversification in institutions. The third priority relates to intensification of research on commodities, commodity groups, and resource management following some basic principles. The fourth priority relates to strengthening translational research and technology management to convert technological breakthroughs to the benefit of farmers and industry. The next two, agricultural education and technology delivery, are the other two pillars of AR4D that have become weak over the years and hence require reorientation and strengthening. The next priority is to increase funding on research, which is inadequate presently, to meet the expanding, complex, and diverse agenda. The next priority is promoting secondary agriculture in and around villages to involve farmers, farmer groups, and producer companies in primary processing, grading, quality and safety awareness, rural energy use, small farmer mechanization, precision farming, and so on with a primary goal of integrating farming and the market, and an ultimate goal of rural entrepreneurship development, creation of rural nonfarm jobs, and more income to link farmers with the market and the industry. The final priority is to equip the research system with soft skills to improve the efficiency and visibility of the research system.

1. Introduction

1.1 Agriculture, Key to Economic Development

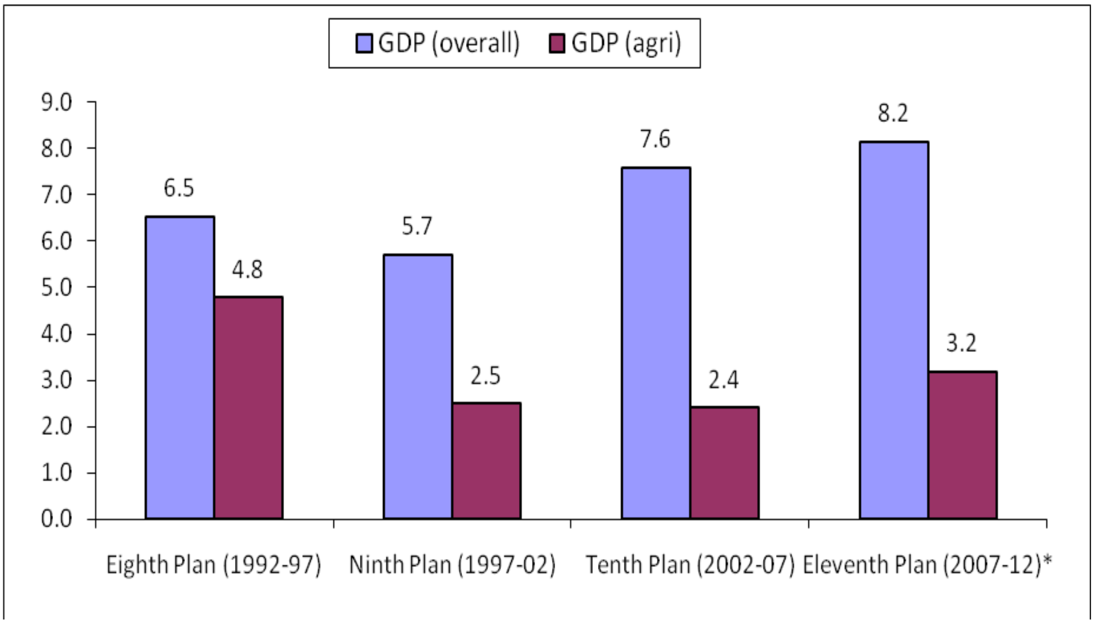
India, a prominent country of South Asia, has shown impressive growth in gross domestic product (GDP) of about 7.35 percent annually from 2000 to 2010. The high rate of growth is also accompanied by some reduction in poverty, from 41.64 percent in 2005 to 32.67 percent in 2010 (at $1.25 per day PPP[1])and from 75.62 percent in 2005 to 68.72 percent in 2010 (at $2 per day PPP), and improvement in Human Development Index from 0.410 in 2000 to 0.547 in 2011 (HDR, 2011). But India still ranks as the home of the poor in the world, with around 36 million people below the poverty line (World Bank 2010). The incidence of poverty is indicated through low per capita income, estimated at INR 53,331 (Indian rupees) in 2010–2011 at current prices (GOI, 2012a). With 17 percent share in global population, India has only 6.4 percent share in global income (GOI 2012b). The numbers of undernourished, underweight—both moderate and severe—(23 percent, while according to NFHS (National Family Health Survey) III data, this number is 45.9 percent for children under three years old) and underheight children (38.40 percent of children below the age of three have been found to be underweight), and low-birth-weight infants (28 percent) are also substantial (Unicef n.d.). As many as 230 million people suffer from hunger (India State Hunger Index, 2008). The 2011 Global Hunger Index estimate for India is 23.7, even worse than Nepal (19.9) and Pakistan (20.7), let alone China (5.5), a country with which India is often compared. The paradox of coexistence of economic growth with high and widespread poverty and hunger is closely linked to the lagging growth rate in agriculture, a predominant sector of the Indian economy. Being a source of both livelihood and food security for a vast majority of low-income, poor, and vulnerable sections of society, the agricultural sector in India, and in particular its future growth, holds the key to poverty and hunger reduction, inclusive growth, and sustainable progress.

1.2 Growth Performance of Agriculture: Some Concerns

India's agricultural sector is facing serious challenges. The growth performance of the sector has been not only low but also widely fluctuating across the government's Five-Year Plans, or FYPs (Figure 1.1) (India, Department of Agriculture and Cooperation 2012). The rate of growth has dropped from 4.8 percent during the 8th FYP (1992–1997) to 2.5 percent in the 9th FYP (1997–2002), 2.4 percent in the 10th FYP (2002–2007), and 3.3 percent in 11th FYP (2007–2012). Further, the agricultural performance has been about six times more volatile than the overall GDP growth rate (Figure 1.2), indicating the seriousness of the challenge. The regional variation in agricultural growth in India is also a significant concern (Figure 1.3 and Figure 1.4). Since agriculture is a state subject, the overall performance of agriculture at the country level largely depends on policies and investments at the state level. The Central government will partially support and fund through central sector schemes and can only advise the states in matters relating to planning and implementation of even central sector schemes in agriculture.

[1] PPP refers to purchasing power parity

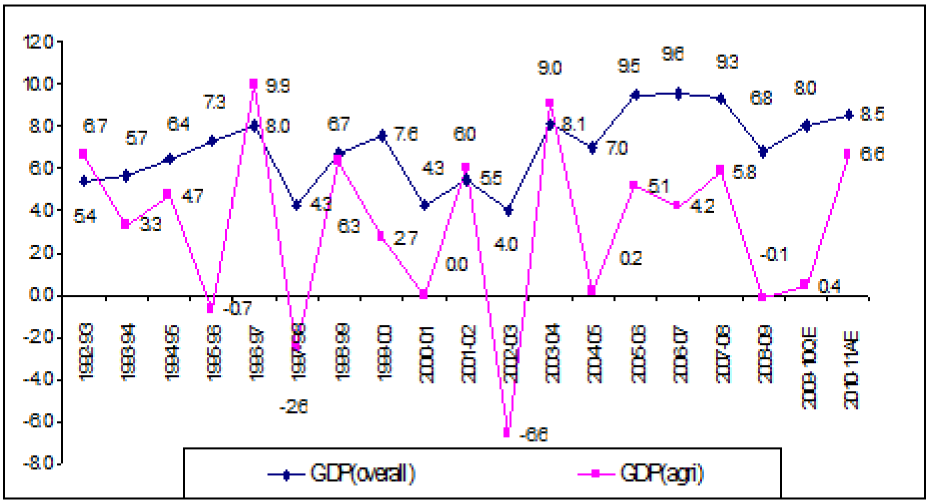
Figure 1.1—Growth rates: GDP (overall) and GDP (agriculture and allied sectors)



Source: CSO, 2011

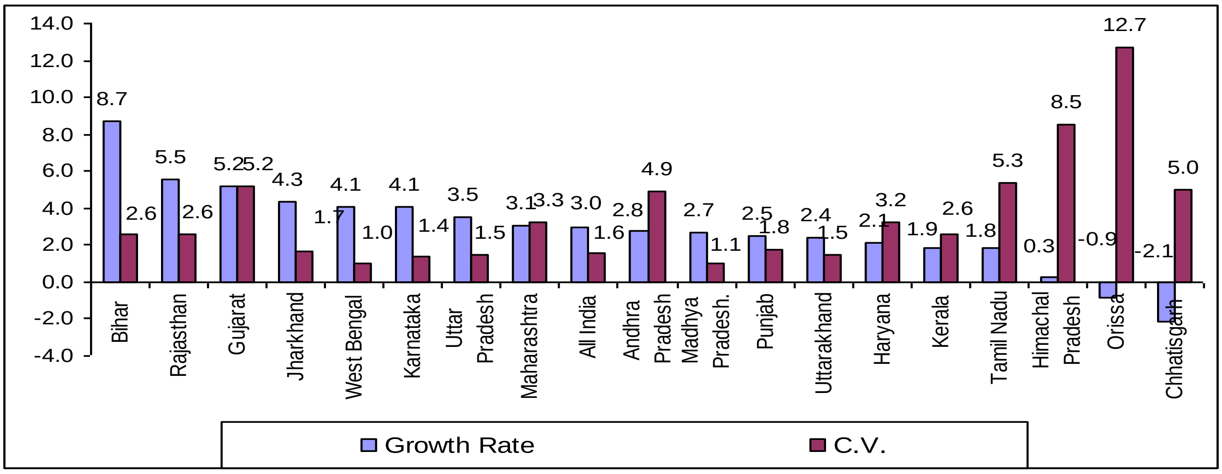
Note: * Figures for the 11th plan show growth rates for the first four years of the plan.

Figure 1.2—Comparative performance of growth of GDP and agricultural GDP



Source: CSO, 2011
Note: Figures are at 2004/05 prices.

Figure 1.3—Average annual growth rate (%) of gross state domestic product from agriculture and allied sectors, 1994/95 to 1999/2000



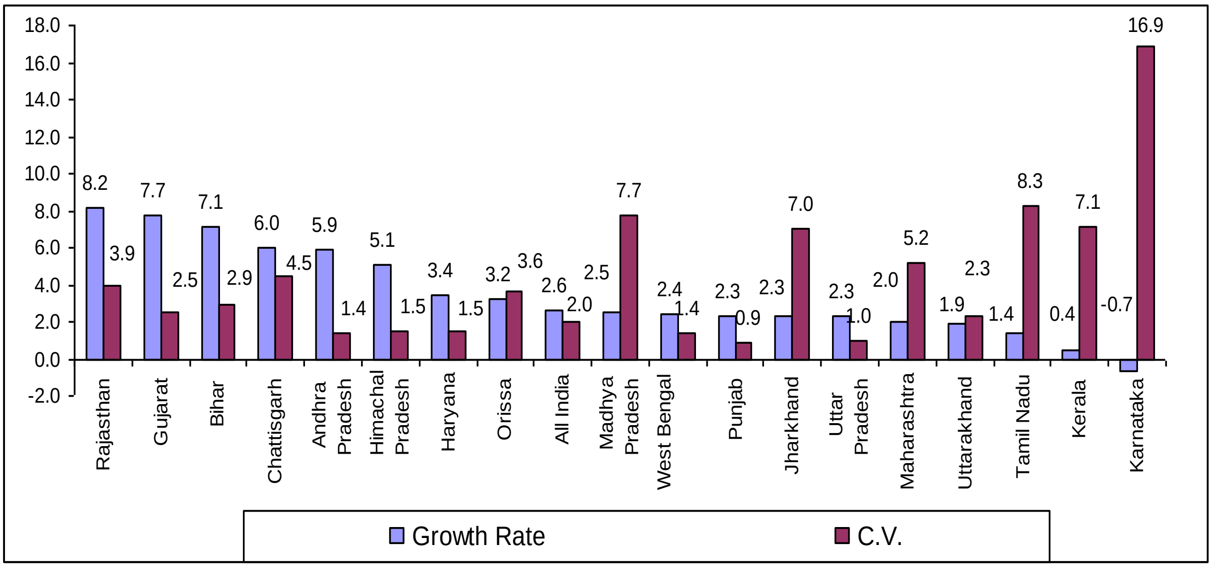
Source: CSO,2011
Note: Gross state domestic product estimates are at 1993/94 prices. C.V., coefficient of variation.

Three major structural changes that occurred in or relating to agriculture since 1990/91 need to be noted when looking at the performance of Indian agriculture: First, the decrease in agricultural share of GDP from 30 percent in 1990/91 to 14.5 percent in 2010/11 indicates a shift from the traditional agrarian economy toward a service-dominated one but without a commensurate decrease in the share of agriculture in employment (50 percent of the population still depends on agriculture for sustenance[2]). Second, the share of income from nonfarm activities has increased within the rural

[2] In most parts of the country, 43.4% of men and 27.5% of females still work as agricultural labor (NSSO, 2001 census data). As far as cultivators are concerned, 36.5% of males and 42.4% of females formed a part of the workforce practicing cultivation, as per the census of 2001.

economy. Third, the average size of operational holdings has diminished progressively from 2.28 hectare (ha) in 1970/71 to 1.55 ha in 1990/91 and 1.23 ha in 2005/06 (Figure 1.5).

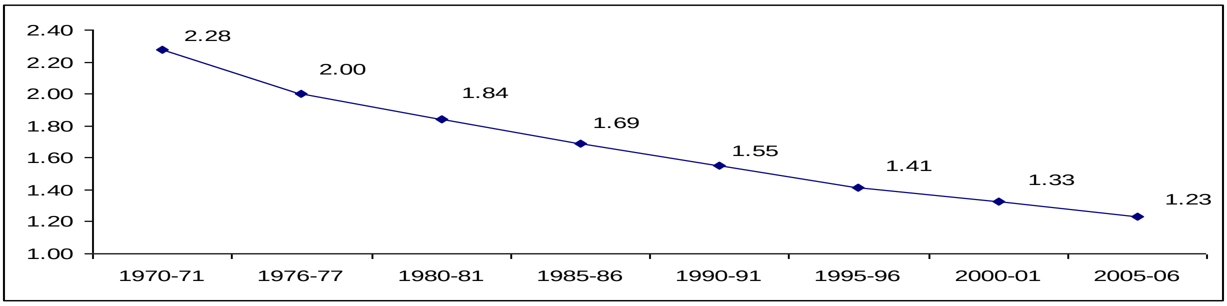
Figure 1.4—Average annual growth rate (%) of gross state domestic product from agriculture and allied sectors, 2000/01 to 2008/09



Source: CSO, 2011

Note: Gross state domestic product estimates are at 1999/2000 prices.

Figure 1.5—Average size (ha) of operational holdings (for all size groups)

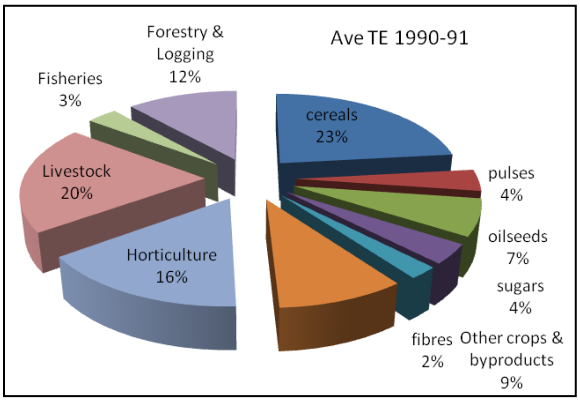


Source: Department of Agriculture and Cooperation, Agricultural Census Division, Ministry of Agriculture.

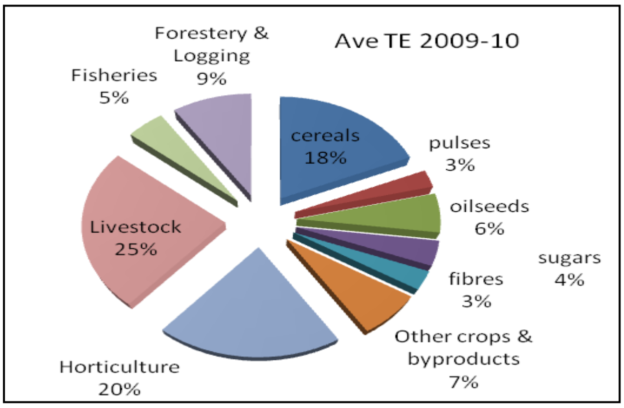
Yet another structural change occurred in the composition of agriculture, leading to diversification of Indian agriculture into high-value commodities from horticulture, livestock, and fisheries since the 1990s (Figure 1.6). The share of fruits and vegetables and livestock has shown an increasing trend in recent years, at a much faster rate than the traditional crops sector. Closely following diversification, or leading to diversification, is the diet revolution in India. The per capita monthly consumption of cereals has declined from 14.80 kg in 1983/84 to 11.35 kg in 2004/05 in the rural areas. In the urban areas, it has declined from 11.30 kg in 1983/84 to 9.37 kg in 2009/10. With the economy growing at about 8 percent, and higher expenditure elasticity of fruits and vegetables, livestock, and fishery commodities than of cereals, increasing pressure is on the prices of such high-value perishable commodities. The agricultural production basket and the distribution system are still not fully aligned to the emerging demand patterns.

Figure 1.6—Composition (%) of output of agriculture and allied sectors

Triennium 1990/91



Triennium 2009/10



Source: CSO,2011

Fully realizing the poor performance of agriculture sector against the targeted growth rate of 4 percent after the 8th FYP, the government has endeavored to reverse the growth trend during the 11th FYP. The record food production of 244.78 million tons during 2010/11 followed by even greater food production of 250.42 million tons in 2011/12 indicates definite success toward this objective. It is reported that agricultural GDP growth has accelerated to an average of 3.9 percent during 2005/06 to 2010/11, partly because of initiatives taken by the government since 2004.

With no or limited options for area expansion, the main source of long-term output growth is improvement in yields. A comparative picture in average annual growth rates of area, production, and yield of different crops for two periods, 1990/91 to 1999/2000 and 2000/01 to 2010/11, is given in Table 1.1. The main points to be noted from the table are (1) the area response through the crop substitution effect for gram, tur, total pulses, rapeseed and mustard, soybeans, and sugarcane is mainly price and program driven, and for maize, groundnuts, oilseeds, and cotton, is technology driven; and (2) growth rates of rice, wheat, gram, tur, total pulses, rapeseed and mustard, soybeans, and sugarcane yields have plateaued and need renewed research.

Table 1.1—All India average annual growth rates of area, production, and yield of principal crops (%)

Crops/Crop Groups	1990/91 to 1999/2000			2000/01 to 2010/11*		
	A	P	Y	A	P	Y
Rice	0.70	2.09	1.36	–0.45	1.25	1.47
Wheat	1.62	4.52	2.87	0.63	1.28	0.57
Maize	0.85	2.24	1.37	2.61	6.88	3.98
Coarse Cereals	–2.42	–0.08	2.03	–0.40	4.60	4.58
Total Cereals	–0.12	2.29	2.38	–0.17	1.69	1.65
Gram	0.88	3.86	2.97	4.33	6.42	1.18
Tur	–0.45	1.89	2.03	2.72	2.00	–0.65
Total Pulses	–0.91	1.06	1.82	2.25	3.93	1.18
Total Foodgrains	–0.27	2.19	2.43	0.26	1.82	1.32
Groundnut	–2.25	–2.40	–0.30	–0.93	11.91	11.44
Rapeseed and Mustard	2.28	4.82	2.96	2.11	5.56	2.67

Soybeans	11.01	16.37	4.67	4.11	8.24	4.16
Total Nine Oilseeds	0.75	2.53	1.76	1.13	6.49	4.86
Total Oilseeds	0.92	2.26	2.09	1.42	4.66	3.71
Sugarcane	2.25	3.11	0.85	2.08	2.02	–0.17
Cotton	1.42	2.12	0.49	2.50	9.46	6.34
*Growth rates are based on fourth advance estimates for 2010/11.						

Note: A = area, P = production, Y = yield.
Source: Directorate of Economics and Statistics, Ministry of Agriculture.

Natural resources like land, water, and ecosystem are dwindling and degrading, causing adverse effects on sustainability and prospects of future growth. The incidence of pests and diseases in crops and animals is increasing and not confined to a particular or limited geographical area but of a transboundary nature. The other big-ticket challenges staring at Indian agriculture include climate change, diversion of food crops to biofuels production, escalating energy prices and price spikes, and excessive price volatility.

1.3 Drivers, Opportunities, and Challenges of Growth in Indian Agriculture

The main drivers of growth are increasing investment, strengthening irrigation, improving seed and fertilizer, price policy, creating marketing and warehousing facilities, progressive marketing, linking credit with marketing, and accelerating the pace of economic policy reforms**.** The opportunities for growth include new technological options, possibilities to harness agriculture to deliver environmental services, changing demand patterns leading to emergence of new agriculture of high-value products, evolving value chains and upcoming dynamic markets and supermarkets, increasing development of entrepreneurship and jobs in the emerging rural nonfarm economy, revolution in information and communication technology (ICT), institutional innovations including the new roles for the state, increasing interest and entry of the private sector, and the civil society and globalization. The challenges for growth include dwindling and degrading natural resources, climate change, the energy crisis, growing urbanization, and widening rural–urban income disparity with the prediction that in the next 20–25 years about 60 percent of people will live in urban settings, which will have implications on agriculture, urban poverty, income distribution, and overall pace and pattern of economic development.

From the above account, it is clear that agriculture and allied sectors in the country have to be better supported and managed than ever before to convert every challenge into an advantage and every opportunity into output and outcome. These concerns are adequately elaborated (India, Ministry of Agriculture 2000) in National Agricultural Policy and National Policy for Farmers (India, Ministry of Agriculture 2007). If these policies are not faithfully implemented, the possibility of disastrous consequences in terms of production, food and nutrition security, vulnerability, economic stability, well-being, and even survival of a large percent of vulnerable groups is imminent. Though agriculture has a strong record in development, somehow it has been underused or unused for development (World Bank 2008) so far. It is time now to give agriculture a new deal.

1.4 Objectives

To make agriculture a strong option and driver for spurring growth, overcoming poverty, and enhancing food security in the region, sharp increase in productivity in smallholder farming is vital. One of the effective and time-tested instruments in using agriculture for development through productivity enhancement is promoting innovation through science and technology. For this, sharply increased investments in AR4D must be at the top of the policy agenda. In a report of the South Asian Group on AR4D in the Asia Pacific region (Mruthyunjaya and Kumar 2010), three to four times increase in funding support to agricultural research, extension, and education from US$1.6 billion[3] in 2002 to $4.6 billion in 2020 (at current prices) is suggested. The Global Conference on Agricultural for Rural Development (GCARD) has deliberated the issues of intensification and diversification of agriculture in the region and recommends that further efforts be made in defining and executing a pro-poor and pro-growth AR4D strategy by collecting more evidence on what has worked in the past, what investments are being made at the present, and what priorities should be set for the future. This has become especially important subsequent to GCARD because of significant climate change effects and frequent global economic shocks in the form of food price inflationary trends that adversely impact the poor, especially in developing countries. This report attempts to make a case for the importance of meeting this need.

1.5 Methodology

In an effort to increase smallholder productivity, this report aims to provide prioritization of agricultural research investments for India, to assess innovative funding mechanisms, and thus to refine the agricultural research agenda suggested by GCARD for India. In this exercise, the demand-driven approach in setting research priorities is used based on perspectives of all major stakeholders along with scientists in the research system. Further, research priorities are identified with a clear focus on target clients (such as resource-poor smallholder farmers, women farmers), target domain (harsh ecologies like hills and mountains, rainfed areas), and research approach (farming system, bottom-up as well as top-down). To do this, a comprehensive analysis is explained with a focus on the following:

1. Reviewing structural concerns in AR4D funding
2. Including views from the demand side (farmer groups, civil society, and private sector) through a series of policy dialogues
3. Assessing the potential of selected agricultural technologies on yield improvement, production cost reduction (such as labor and input cost reductions or natural resource use reduction), sustainable natural resource use, food production, and trade
4. Developing a strategic plan for enhanced AR4D prioritization for India, including recommendations for AR4D research prioritization, expanded investment sources, and innovative AR4D delivery

1.6 Outline of the Report

A comprehensive analysis of the AR4D needs of India and the investment priorities resulting from these needs is attempted and set forth in this report by drawing on existing literature; insights from experts; country dialogue with 32 carefully selected key stakeholders representing government, civil society, private sector, academia, and farmer organizations connected with AR4D; and the collaborator's own experience. The outline of the report is as follows:

1. Introduction, objectives, methodology and chapter outline
2. A critical review of key national policies and institutions that influence AR4D priority setting, financing, and execution

[3] All dollar amounts are expressed in U.S. dollars.

3. A critical review of structures, processes, and issues related to priority setting, financing, and execution
4. A synthesis of studies and views from stakeholders on AR4D priority setting, financing, and execution
5. An analysis of potential new technologies
6. A strategic plan for enhancing AR4D with improved research prioritization, expanded sources of funding and investment, and innovative delivery and dissemination

2. A Critical Review of Key National Policies and Institutions That Influence Agricultural Research for Development Priority Setting, Financing, and Execution

2.1 National Policy Formulation

Since its independence in 1947, India has been following systematic planning for economic development through Five-Year Plans (FYPs) formulated by the Planning Commission of India. India is now in the 12th FYP, as of April 1, 2012. Each FYP is formulated on the basis of experiences of the previous plans, current government policies, and projected requirements of the future as reflected in the recommendations of various working groups. The government frames policies on various sectors and subsectors to achieve specific objectives of development and get them approved by the Indian Parliament.

The Indian government, at both the central and state levels, formulates and issues policies related to different sectors including agriculture and thrust areas from time to time. For example, India has policies on national forests, water, energy, industry, eximexport-import, health and education, labor and employment, environment, and so on. Although these policies are formulated and issued in consultation with all the relevant ministries and departments, the coordination among these ministries and departments is uncertain while the policies or programs are implemented.

For agriculture specifically, India has a National Agricultural Policy (NAP) approved by the Parliament in 2000 and a National Policy for Farmers (NPF) approved by the Union Cabinet in 2007. There is no agricultural research policy as yet. But recently, a Committee of Science Secretaries, which includes the secretary of the Department of Agricultural Research and Education, has been developed by the government of India to frame such a policy.

The NAP aims to establish an agrarian economy that ensures food and nutrition to India's billion people, raw materials for its expanding industrial base and surpluses for exports, and a fair and equitable reward system for the farming community for the services they provide to the society. It emphasizes the critical role of generation and transfer of agricultural technology with a focus on regionalization of agricultural research based on identified agroclimatic zones, application of frontier technologies, upgrading of agricultural education and its orientation toward uniformity in education standards, women's empowerment, user orientation, vocationalization, and promotion of excellence. It also emphasizes the introduction of an innovative and decentralized extension system to make it farmer responsible and farmer accountable and to move toward a regime of financial sustainability (realistic cost recovery) of extension services, while simultaneously safeguarding the interests of the poor and vulnerable groups. The NAP was criticized of being more generic, unfocused, and farmer centric.

The NPF claims to be much more comprehensive than NAP and aims at improving the economic viability of farming through substantially improving net income of farmers. It focuses on increased productivity; profitability; institutional support; and improvement of land, water, and other support services apart from provisions of appropriate price policy, risk mitigation measures, and so on. It emphasizes the centrality of farmers in the development with focus on improving profitability in farming, empowering women farmers, and restoring respectability to farming and farmers. It has pleaded for enhanced budget outlay for agricultural research for development (AR4D), strengthening the national agricultural research system (NARS), and agricultural education. It has suggested some organization and management (O&M) reforms in the NARS to make the system more efficient and accountable. Though several government initiatives since 2007—like the National Horticulture Mission, National Bamboo Mission, reforms in agricultural marketing, revitalization of cooperative credit structure, National Fish Development Board, National Food Security Mission, Rastriya Krishi Vikas Yojana, National Rainfed Area Authority, and others—are in consonance with the intent, direction, and measures suggested in the NPF, it is not very clear that how these initiatives are really derived and drawn from the NAP and NPF in their prioritization, allocation of resources and budget, implementation, and so on.

Table 2.1 provides an inventory of changing national policy concerns, articulated policy agenda of research and research priorities, research system response, and main research and technology delivery approach, followed with broad results and impact over five different periods (beginning with the planning era of 1950 to 1970, then 1970 to 1990, 1990 to 2000, 2000 to 2011, and the 12th FYP of 2012–2017). Table 2.2 shows the evolution of public AR4D institutions in India.

Table 2.1—Policy agenda and analysis of agricultural research for development

Period	Main National Policy Concerns / Development Priorities	Policy Agenda of Research / Research Priorities	Research System Response	Research Approach	Transfer of Technology to Farmers	Expected Results / Impact
1950–1970	• Food shortage	• Increasing productivity	• Large investment to establish public research institutions, funding, and operating projects • Growth rate of research & education (R&E) expenditure: 8.6% per year (Jha & Kumar, 2005) • Intensity (%): 0.11 of agricultural GDP • Scattered few central institutes, regional centers and stations, commodity boards, and agricultural colleges addressing regional problems (NARI)	• Input intensive (chemicals, water) • Land-based, resource-endowed area • Top-down / participatory research • Exploit biological potential of important food crops (commodity and/or discipline focus)	• Public extension system functional (Department of Agriculture—community development, national extension system, Intensive Agricultural District Program; Indian Council of Agricultural Research—national demonstrations, commodity boards, media-All India Radio)	• Inputs and service delivery system OK • Green revolution • Only main food crops • Poor not much benefited • Bypassed rainfed areas and crops • Landless: not much employment generated

Period	Main National Policy Concerns / Development Priorities	Policy Agenda of Research / Research Priorities	Research System Response	Research Approach	Transfer of Technology to Farmers	Expected Results / Impact
1970–1990	• Rural poverty • Environment (soil and water management) • Profitability • Nutrition • Export • Pulses and oilseeds • Mountain of food or food shortage	• Genetic resources and productivity • National resource management (NRM) (water & soil) • Diversification • Postharvest management (PHM) • Oilseeds • Pulses • Stakeholder participation • Attention to human resource development and research infrastructure at research station level	• Further investment in strengthening / spreading, NRM, livestock, poultry, horticulture, fisheries research institutions / projects across the country • Growth rate of R&E expenditure: 3.5% (Jha & Kumar) (Av.) • Intensity (%): 0.22 (NARS)	• Input use efficiency • Rainfed area focus • Non-farm-based, diversified enterprises • Participatory research • Multiproduct, interdisciplinary focus • National Academy of Agricultural Research Management (NAARM) • Externally aided projects (EAPs): Agricultural Human Resource Development, National Agricultural Research Project (NARP)	• Strengthening and decline of public extension system • Exploring models of public extension system (training and visit system, NGOs, input industries • Indian Council of Agricultural Research (ICAR): operation research projects, Lab to Land, Krishi Vigyan Kendra (KVK) system • Growth rate of agricultural extension expenditure 9.54%	• Milk, egg, fruit and vegetable, fish revolutions • Trends in reduction in poverty • Some resilience in agriculture • Symptoms of strains on natural resources

Period	Main National Policy Concerns	Policy Agenda of Research / Research Priorities	Research System Response	Research Approach	Transfer of Technology to Farmers	Expected Results / Impact
1990–2000	• Economic reform / globalization • Rural poverty • Environment (soil and water management) • Profitability • Nutrition • Export • Pulses and oilseeds • Food shortage	• Genetic resources / productivity • NRM (soil and water) • Oilseeds • Diversification • Gender • Policy (National Center for Agricultural Economics and Policy Research, NCAP) • Participatory research • Organization & management (O&M) reforms • Public/private–sector Partnership (PPP) • Prioritization • Human resource development (HRD) • Frontline extension	• Further investment in oilseeds, horticulture, livestock, seed spices • Expansion of KVK • Growth rate of R&E expenditure: 3.38% • Intensity (%): 0.35 (Agricultural Science Technology Indicator, ASTI) (NARS)	• Input use efficiency • Non-land-based enterprises / diversification • Participatory research • Multiproduct, interdisciplinary • Women (National Research Center for Women) and policy research (NCAP) • National Agricultural Technology Project (NATP) / O&M reforms / PPP / research prioritization • Establishment of disciplinary State Agricultural Universities (SAUs) • Restrictions on recruitment	• Decline of public extension system • Successful Agricultural Technology Management Agency (ATMA) experiment • Expansion of KVK system • Growth rate of agriculture extension expenditure: 2.76%	• Input-driven growth / deceleration in productivity • Not many economic reforms in agriculture • World Trade Organization (WTO) not benefitting agriculture • Very slow reduction in poverty • High malnutrition • Further strain on natural resources • Climate change becoming apparent • Energy problem becoming apparent

Period	Main National Policy Concerns / Development Priorities	Policy Agenda of Research / Research Priorities	Research System Response	Research Approach	Transfer of Technology to Farmers	Expected Results / Impact
2000–2011	• Price volatility • Food insecurity • Environment (soil and water management) • Energy • Nutrition • Profitability • Poverty • Pulses	• Genetic resource / productivity • Abiotic stress • Biotic stress • Biotechnology • NRM & climate change • PPP • Participatory research • Smallholder focus • Gender focus • HRD • Value chain • Livelihood security • Collaboration with Consultative Group on International Agricultural Research (CGIAR) institutions	• Further investment in horticulture, microorganism, insects bureau • Growth of R&E expenditure: 3.48% (Singh A, 2011) • Intensity (%): 0.34 (ASTI) (NAIS)	• Input use efficiency • Non-land-based enterprises / diversification • Participatory research • Multiproduct, interdisciplinary • Women and policy research • National Agricultural Innovation Project (NAIP), value chain, sustainable livelihood security, National Fund for Basic and Strategic Research, O&M reforms • Priority setting, monitoring & evaluation (PME) • Stress on PHM processing • More involvement of private sector • Interface with development departments and CGIAR institutions • Emphasis & efforts on recruitment	• ATMA established / replicated, agriclinic and agribusiness consortium scheme • Media—print & TV, private initiatives, Internet, mobile • Private sector—agribusiness, contract farming, private consultancy, NGOs, producer companies, financial advisers, and so on • KVK further expanded, one or more than one in each district • Attempt to forge linkage of ATMA with KVKs • Growth rate of agricultural extension expenditure: 6.23%	• Initial deceleration but some revival in production • Soaring and highly volatile commodity prices • Further strain on natural resources • Energy crisis • Inadequate processing and value addition • Human resource stress in quality and quantity • Gender concerns remain weak • Interdisciplinary research less • Communication and policy dialogue weak • Private-sector participation notional or insufficient • Slow reduction in poverty and malnutrition • Labor shortage and slow pace of farm mechanization • Development interface notional / much wanting

Period	Main National Policy Concerns / Development Priorities	Policy Agenda of Research / Research Priorities	Research System Response	Research Approach	Transfer of Technology to Farmers	Expected Results / Impact
2012–2017	• Price volatility • Land, water, and climate • Energy • Market and logistics • Food insecurity • Nutrition • Health • Education and skill • Rainfed agriculture • New technologies • Seed systems • Livestock and fisheries	• Productivity, input use efficiency, and profitability • Climate-resilient agriculture • Secondary agriculture • Development of quality human resources	• Further investment in biotic, abiotic, and biotech research • Climate change • PHM • HRD • Translational research	• Agricultural innovation and incubation fund • Policy for R&D in agriculture • Research platforms (22) • Technology parks • Business Planning and Development units • Extramural funding • Secondment of scientists • Farmers first • Student ready	• ATMA in all districts • Further expansion of KVKs • Forging linkage of ATMAs & KVKs	• Faster and sustainable production • Stable prices • Energy security • Value-chain development • Strengthened higher education & skill development • PPP

Source: Compiled from various sources

Table 2.2—Evolution of public agricultural research and development institutions in India

Time Period	Indian Council of Agricultural Research (ICAR) Commodity-Oriented Institutions dealing with	ICAR-Resource / Region-Oriented Institutions dealing with	State Agricultural Universities / Units
Pre-1950s	IARI, rice, sugarcane breeding, cotton, lac, tobacco, research institutes under commodity committees, veterinary science, inland fishery, marine fishery		Agricultural research stations in states Agricultural colleges at Pune, Nagpur, Kanpur, Coimbatore, Sabour, Delhi
1950s	Sugarcane, jute & allied fibers, potato, dairy, fishery technology *Maize	Arid agriculture, soil survey & land use planning, agricultural statistics	Uttar Pradesh-1
1960s	Tuber crops, horticulture, jute technology, sheep & wool, fishery education *Millet, sorghum, rice, wheat, pulses, oilseeds (castor and soybean), tuber crops (other than potato), sugarbeet, sugarcane, cotton, jute & allied fibers, forage crops, buffalo, poultry (breeding)	Grass & fodder, soil salinity Dryland agriculture, tillage requirements for different cropping systems, soil test for crops response, micro and secondary nutrients, microbial decomposition and organic wastes, long-term fertilizer experiments, water management, groundwater utilization through wells and tubewells, biological control of insect pests	Assam, Karnataka-1, Madhya Pradesh-1, Maharashtra-1&2, Orissa, Punjab
1970s	Wheat, oilseeds, groundnut, cotton, subtropical horticulture, plantation crops, avian, goats, freshwater aquaculture *Tobacco, potato, spices, subtropical fruits, tropical fruits, arid zone fruits, cashew nut, coconut and arecanut, vegetables, floriculture, oilseeds (safflower, palm, sunflower), honeybee, composite fish culture and exotic fish, freshwater fishery, marine fishery, brackishwater fishery, fish culture (air breathing), cattle, pig, sheep (mutton and wool), dressed poultry and piggery products	Plant genetic resources, soil & water, agricultural engineering, agricultural research management, hill agriculture (Almora), regional center for Goa, regional center for Andaman & Nicobar Islands, NER (North Eastern Region) hills Stocking of fish seed, ecology of freshwater fishery, riverine carp collection technique, transportation of fresh fish, managing reservoir fishery, riverine fish seeding, evolving methodology for using surplus milk, costing of chilling and transportation of milk to city dairies, epidemiological studies on foot & mouth diseases, blood	Andhra Pradesh, Bihar-1, Gujarat-2&3, Haryana, Himachal Pradesh-1, Kerala, Maharashtra-3&4, Tamil Nadu-1, Uttar Pradesh-2&3, West Bengal-1, National Agricultural Research Project (NARP)-Zonal Research Stations

		groups and biochemical polymorphism, canary coloration of wool, biological control of weed-parasitic nematodes, rodent control, biological nitrogen fixation, solar energy utilization, white grub, salt-affected soil and saline water, postharvest technology of horticultural crops, seeds (crop)	
1980s	Sorghum, maize, rice, pulses, soybean, vegetables, mushroom, citrus, spices, cashew, cattle, buffalo, yal, mithun, camel, equine, brackishwater aquaculture, coldwater fishery *Pearl millet, small millet, underutilized crops, arid legumes, rapeseed & mustard, mushroom, cashew, ornithology, betelwine	Cropping systems research, soils, postharvest technology, integrated pest management, plant biotechnology, agroforestry, weeds, fish genetic resources, animal genetic resources, dryland agriculture, Eastern Region center Agrometeorology, diara (waterlogged) land, herbicide residues in horticultural crops, management of apple scab, weed management (Brahmputra Valley, sorghum, fodder crops), agroforestry, animal energy and system efficiency, monitoring/surveillance/forecasting of animal diseases, processing and storage of khandsari and jaggery, plastics in agriculture	Bihar-2, Jammu & Kashmir-1&2, Himachal Pradesh-2, Karnataka-2, Madhya Pradesh-2, Rajasthan-1, Tamil Nadu-2

1990s	Rapeseed & mustard, oilpalm, temperate horticulture, arid horticulture, grapes, banana, medicinal and aromatic plants, orchids, onion & garlic, meat and meat products, poultry *Groundnut, chickpea, pigeonpea, goat	DNA fingerprinting, seed spices, water management, biological control, animal nutrition & physiology, women in agriculture, agriculture economics & policy Animal genetics, drainage under actual farming conditions, farm implements and machinery	Maharashtra-5, Manipur, Rajasthan-2, Uttar Pradesh-4&5, West Bengal-2&3, Punjab-2, Central Agricultural University—Manipur
2000s	Makhana, litchi	National Bureau of Agriculturally Important Microorganisms National Bureau of Agriculturally Important Insects, National Institute of Abiotic Stress Management	Andhra Pradesh-3, Bihar-3, Chattisgarh-1, Haryana-3, Gujarat-4, Karnataka-3&4, Kerala-2&3, Madhya Pradesh-3, Rajasthan-3, Uttrakhand-2

Source: Jha and Kumar 2005, with recent additions.

Notes: Numbers in the last column indicate the number of universities in a state. Central Agricultural University—Manipur was established by the ICAR. * denotes All India Coordinated Research Projects (AICRPs). In several cases, AICRPs were upgraded as centers/directorates/institutes.

2.2 Begging Bowl to Food Self-Sufficiency (Green Revolution): 1950–1970

During the period from 1950 to 1970, India faced droughts and floods; and with increasing population, shortage of food was the main policy concern and development priority of the government. The country had to import food grains in larger quantities, much to the embarrassment of the government and the people of India. Increasing productivity of food crops was the main policy agenda and research priority as well. Accordingly, the government made large investments in establishing and funding several crop-based research institutions and projects including the establishment of the Indian Council of Agricultural Research (ICAR). The scattered agricultural research institutions in the country were brought under the management of ICAR to provide a sense of direction, focus, and leadership and to bring in economies of scale. This was a landmark time period with everything needing to work in symphony to usher in a much-acclaimed, celebrated green revolution: technology to boost productivity; focused objectives; leadership to enable policies and institutions; effective inputs; services and extension delivery system; and above all, committed scientists, policymakers, and hardworking farmers. No doubt it was the golden period of development and glory in Indian history. However, the pattern of growth in agriculture has brought in its wake uneven development across regions (for example, dryland areas bypassed) and crops (most commonly rice and wheat) as also across different sections of the farming community (small and marginal farmers, agricultural laborers) and degradation of natural resources (soil and water) in some areas (India, Ministry of Agriculture 2000).

2.3 Beyond the Green Revolution: 1970–1990

During the next period, 1970–1990, policy concerns included the increasing rural poverty and regional disparity, natural resource (soil and water) degradation, malnutrition, rising input costs and falling profitability, rising net imports, shortage of pulses and oilseeds, stagnating yields, and persisting food insecurity. Accordingly, the policy agenda and research priorities of the NARS emphasized conservation and improvement of genetic resources to raise productivity, sustainable natural resource management, diversification, postharvest management, pulses and oilseeds, stakeholder participation in research planning, human resource development (HRD), and infrastructure strengthening at the research stations. To pursue these priorities, ICAR has made further investment to strengthen by spreading national resource management (NRM), livestock, poultry, horticulture, and fishery research institutions and projects across the country (Table 2.2). The amalgamation of the scattered research institutions with the national agricultural system that began in the previous period was complete during this period and the system thus graduated from NARI (National Agricultural Research Institute) to NARS. It was growing in size and complexity and considered as one of the largest NARSs in the globe. However, the resource crunch for supporting expanding research agenda was being felt. Based on the lessons learned during 1950–1970, the approach and strategy of NARS was amended with focus on input use efficiency, rainfed areas, diversification, rural nonfarm enterprises, greater stakeholder participation in research management, and multiproduct and interdisciplinary research.

Two World Bank–supported projects, namely, National Agricultural Research Project (NARP) to strengthen regional research capacity with focus on research infrastructure development, and Agricultural Human Resource Development to strengthen and bring in reforms in the agricultural education system, were launched and implemented during this period in ICAR institutes and state agricultural universities (SAUs). Sincere efforts were also made to strengthen the public extension system through the National Agricultural Extension Project and the training and visit system, again with the assistance of World Bank. These projects no doubt made some difference, but their impact could not be fully sustained after their completion. Other models of involvement such as nongovernmental organizations (NGOs) and input industries in extension were also tried. ICAR continued frontline extension efforts through Operation Research Projects initially, Lab to Land later, and finally Krishi Vigyan Kendras (KVKs). The period was successful in heralding the famous milk, egg, fruit and vegetable, fish, and oilseeds revolution; in some reduction in poverty level; and in some resilience in agriculture through better program management, particularly in problem areas. However, stress on natural resources continued.

During this period, notwithstanding NARS's contribution to usher in milk, egg, fruit and vegetable, fish, and oilseeds revolution, it is significant to note the three committees—Gajendragadkar Committee, Chandrasekhar Singh Committee, and GVK Rao Committee—that were appointed to review different aspects of the functioning of ICAR. They were set up mainly to review the O&M issues including HRD problems associated with the expanding size and complexity of ICAR. Several institutional and process changes were suggested, many were approved and introduced as such, and others were approved or introduced with changes.

2.4 Economic Reforms: 1990–2000

During 1990–2000, India introduced macroeconomic reforms and trade liberalization covering imports, exports, credit, and finance. Globalization following the formation of the World Trade Organization (WTO) exposed the hitherto-protected Indian agriculture to global changes in prices, competitiveness in cost and quality, barriers to trade, and so on. The National Agriculture Policy was formulated and approved during this period. The concerns of rural poverty, natural resource degradation, rising costs and falling profitability in farming, malnutrition, export pressure, and shortage of pulses and oilseeds were stressed during this period. The inputs and services delivery system was weak and not supportive enough for the opened and liberalized economy.

The research agenda and priorities of the national research system included strengthening of genetic resources conservation and improvement to contribute to productivity enhancement, further strengthening of research in NRM issues, pulses and oilseeds, diversification, policy and gender analysis, participatory research management, O&M reforms, public/private–sector partnerships (PPPs), research prioritization, HRD, and strengthening frontline extension activities through further expansion of KVKs. The research system made more investments in establishing institutions in oilseeds, horticulture, livestock, seed spices, and expansion of KVKs. The research approach and strategy of NARS consisted of enhancing input use efficiency, focus on non-land-based diversification, multiproduct and multidisciplinary research, and policy and gender analysis. ICAR started implementing the World Bank–supported National Agricultural Technology Project (NATP) with a focus on agroecosystem research from the production system perspective, to generate potential technologies; mission mode research and competitive grant scheme; innovations in technology generation and transfer; Agricultural Technology Management Agency (ATMA); Institute Village Linkage Program–Technology Assessment and Refinement scheme; and O&M reforms covering research management, PPPs, priority setting and monitoring and evaluation (PME), and so on. In agricultural education, a new trend of establishing disciplinary-based SAUs started with almost no additional manpower and resources, mostly by carving them out from the existing SAUs. Thinly spreading the resources without creating adequately trained and skilled manpower went unabated and led to a crippled agricultural research and education system in India.

The decline in the public extension system was more visible, though attempts were made to strengthen the system via decentralization at and below the district level. Specifically, ATMA was being tried under the National Agricultural Technology Project (NATP) in 28 pilot districts in the country. The role and involvement of NGOs, KVKs, farmer organizations, cooperatives, the corporate sector, and paratechnicians in agricultural extension were also emphasized. During this period India witnessed deceleration in productivity, economic reforms were minimal in agriculture, WTO was not found beneficial to the farming community, the rate of decline in poverty slowed, malnutrition increased, further strain on natural resources was reported, climate change effects became more visible, and the energy problem became acute. Also during this period, ICAR was again reviewed by Tata Consultancy Services to identify O&M issues at ICAR's headquarters and to suggest remedial measures.

2.5 Revival of Agriculture: 2000–2011

During the period from 2000 to 2011, the dominance of the agricultural market was painfully apparent amid production failures. National policy concerns of this period included high price volatility; shortage of food, particularly perishables like fruits and vegetables, milk, eggs, and others; natural resource degradation; energy shortage; malnutrition; rising costs and falling profitability; slow rate of decline in poverty; and shortage of pulses. To address the agrarian crisis identified with increasing rates of farmer suicides, the National Policy for Farmers (NPF) was formulated and approved to increase the net income of farmers. Weaknesses of the input and service delivery system increased.

The NARS policy agenda and research priorities included strengthening genetic resource conservation and development, addressing biotic and abiotic stresses, more efforts in biotechnology, strengthening research in NRM and climate change, PPP, participatory research, smallholder- and women-focused research, HRD, value chain, livelihood security, and more international collaboration with institutions of the Consultative Group on International Agricultural Research (CGIAR). During this period, a new World Bank–assisted project, National Agricultural Innovation Project (NAIP), was launched and implemented. NAIP is a higher-generation project to explore the possibilities for pushing the production frontier through basic and strategic research in modern science and technology, bringing more commerce into agriculture through research on value chains, and promoting sustainable livelihood and security of farmers in most remote areas and many process reforms. ICAR further invested in establishing national bureaus with emphasis on service functions relating to insects and agriculturally important microorganisms and in establishing more research institutes in horticulture, besides supporting research in other institutions established earlier. The trend toward opening more and more subject-matter-based SAUs continued during the period.

The research approach and strategy consisted of enhancing input use efficiency, diversification, participatory research, multiproduct and multidisciplinary research, policy and gender research, and further strengthening of basic and strategic research of smaller outlay to partially substitute for AP Cess Fund projects through the National Fund for Basic and Strategic Research, a competitive grant scheme of ICAR. In public extension, ATMA was replicated in all the districts of the country. Agri-Clinics and Agri-Business Consortium were also established by the Ministry of Agriculture. Special extension efforts were made for greater use of media, print, TV, private initiatives, Internet, and mobile technologies. Private-sector and NGO involvement increased: contract farming, private consultancy, formation of producer companies, farmer associations, and so on were observed. KVKs expanded—some bigger districts had more than two—and effort was put into forging the linkage between KVKs and ATMAs.

Despite poor performance of agriculture in the beginning of this period—the problem of food shortage and particularly perishables, volatile prices, and global economic shocks—with the renewed interest of the government via more investment in some key megaprograms and improvement in implementation culture, agricultural growth increased and India produced a record 242 million tons of food during 2010–2011. But this period, which ended the 11th FYP, faced serious concerns: soaring and highly volatile commodity prices and particularly those of perishables, stressed natural resources, shortage of energy, low processing and value addition, stress in human resources both in number and in quality, gender concerns, weak capacity in interdisciplinary research and communication and policy dialogue, slow reduction in poverty, malnutrition, shortage of labor, and slow pace of farm mechanization. Industrial growth suffered and failed to increase employment, particularly of the people migrating from rural areas. The overall the rate of growth of agricultural gross domestic product (GDP) during the 11th FYP is estimated to be 3.3 percent, lower than the targeted 4 percent.

2.6 12th Five-Year Plan: 2012–2017

Currently, the main national policy concerns and development priorities reflected in the Indian government's planning documents include addressing rising and highly volatile commodity prices, declining and degrading natural resources, threats of climate change, energy security, market and logistics, food insecurity, malnutrition, health and sanitation, improved education and skills, rainfed agriculture, new technologies, seed systems, and livestock and fisheries. The policy agenda and research priorities to address these policy concerns include enhancing productivity, input use efficiency and profitability in farming, promotion of climate-smart agriculture, secondary agriculture, and development of quality human resources.

The response of the research system as spelled out in planning documents includes further investment in establishing institutions and supporting projects in biotic, abiotic, and biotechnological research; strengthening research on climate change; value addition, processing and postharvest management; HRD; and translational research. The research approach and strategy planned by the research system will include establishment and operation of an agricultural innovation and incubation fund, developing a policy for research and development (R&D) in agriculture, establishing research platforms in 22 key areas, supporting translational research, establishing technology parks and more business planning and development units, increasing extramural funding for research, secondment of scientists in private-sector and public-sector organization, and following the policy of farmers first (farmer orientation) and student ready (well-equipped students). The trend toward opening subject-matter-based new SAUs is continuing, and a recent tally is reported to be 63 SAUs.

The main mechanisms of technology transfer to famers include strengthening ATMAs in all the districts, further expansion of KVKs, and forging functional linkage of ATMAs and KVKs by sharing tasks and resources. The expected results from these planned or proposed efforts include faster and sustainable production, reasonable and stable prices, energy security, full-scale value-chain development, strengthened higher education and skill development, and increased public/private–sector participation. The overall goal of these efforts is expected to contribute to faster growth (exceeding 4 percent) and sustainable and more inclusive development.

2.7 Overall Picture

A perusal of these five periods suggests alignment of needs, actions, and achievements in the economy, in agriculture, and in AR4D at a broader level, even though India never exceeded or achieved targeted growth rates in agricultural GDP, reduction in poverty, malnutrition, Millennium Development Goals, and others. In a country the size of India, with regional diversity and growing complexity, particularly under frequent global economic shocks, climate change, the energy crisis, and other factors that are not easy to deal with, this is not an average achievement. The Economic Survey 2011–2012 (India, Planning Commission 2011b) states that thanks to 15 years of robust growth and nearly a decade of greater than 30 percent investment rate, the economy now has enough resilience for an optimistic view that India can be the leading engine of global growth; however, the provision is that the performance must significantly be improved by overcoming at least domestic causes of slowdown like inflation, which raises its ugly head every now and then, and better management of pressures of murky politics that has slowed the pace of reforms, particularly in the most vital agricultural sector. The survey further states that the low productivity of Indian agriculture with yield levels of most of the crops lagging behind global levels, combined with lack of improved supply chain from farmer to consumer, is the main concern. Also important is a holistic approach, simultaneously working on AR4D; agricultural education; dissemination of technology; provision of critical agricultural inputs like seed, fertilizers, pesticides, and irrigation; and credit and policy initiatives that raise investment in agriculture and facilitate private players to render supply chain services. With the agricultural research system, particularly ICAR, the failure to convert even the best plan covering an exhaustive array of initiatives with reasonably enough if not excess resources for faithful implementation and systemwide impact is often attributed by review committees and experts to the underlying structure, organizational culture, managerial and financial norms and procedures, innovative or bold policy initiatives, program planning, monitoring and evaluation culture and practice, and so on (India, Planning Commission 2005; ICAR 2005; Jha 2002; Centennial Group 2011; IARI 2012). Agricultural education is facing serious constraints of sufficient and right faculty, inadequate financial resources, and several others. The repeated suggestion to revisit and reform or reorient the system makes the present report further relevant.

3. A Critical Review of Structures, Processes, and Issues related to Priority Setting, Financing, and Execution in Agricultural Research for Development

3.1 The Enabling Environment for Science: Structural Issues

Structures and processes are the soft infrastructure items that determine the enabling environment for science to fully manifest into societal gains. Even if we have the best of science, unless the soft infrastructure is adequate and supportive, nothing significant can be expected from science. In view of stagnating agricultural productivity growth that is reducing food and nutritional security, it can be seen that fragmented food supply chains have failed to provide needed incentives to farmers to stay in farming, sometimes even forcing them to resort to the most extreme steps like committing suicide. There is also underinvestment in agricultural research for development (AR4D) because of lack of resources and the existence of inflexible financial rules suited to conducting good scientific research. Speilman and Lynam (2010) examined specific design elements relating to processes, organizational interaction, and the internal incentive structures that help transform knowledge into action in the Agricultural Innovation System. Using examples in Sub-Saharan Africa, they suggest efforts to introduce structural and formal changes that encourage autonomous and independent processes and innovation within agricultural research organizations. The Report of the Global Author Team (GFAR 2010) categorically recommended transformation of the currently fragmented agricultural research system into a more cohesive one. It has also suggested that the agricultural research system must also become more agile and adaptable in responding to the quickly changing external environment.

Big System. India has one of the biggest agricultural research systems in the world with a staggering number and geographical spread of institutions, an elaborate and enviable variety of structures and processes, multilayer exhaustive and widely consultative resource allocation exercises particularly at the beginning of each Five-Year Plan (FYP), increasing funding, and expanding funding mechanisms. About the size and spread of the Indian Council of Agricultural Research (ICAR), Jha and Kumar (2005) report that it indicates diversification in commodity research and the focus on natural resources and regional capacity creation. But the institutional proliferation in terms of size, spread, and diversity that occurred over time itself has become a concern for efficient management, as observed by Swaminathan Task Force (India, Planning Commission 2005): "The system has grown too large, dispersed and unwieldy because of periodic additions without rationalization and clarity of mandates of the new units vis-à-vis the existing ones. An exercise of integration and consolidation is urgently called for." No doubt ICAR has sincerely tried to rationalize the number of All India Coordinated Research Projects (AICRPs), research stations under it during the 10th FYP at the time of formulation of the plan. But some of these efforts could not lead to expected results, owing to political resistance, procedural difficulties, institutional compulsions, and so on. Further, no mechanism or evidence exists to systematically study the impact of even these efforts on the efficiency and image of the system to guide new changes. Further, the paradigm shift from the National Agricultural Research Institute (NARI) to the National Agricultural Research System (NARS) is still incomplete as all the stakeholders are not fully involved in activity planning, implementation, evaluation, and research governance.

Evolving Institutions. Per the changing context and need, in the public sector, the evolving structure of organizations in promoting Science and Technology (S&T) in agriculture is visible, from the central and state governments to national research organizations, state agricultural universities (SAUs), and other public-sector organizations and entities involved in AR4D.

The limited entry of the private sector in pursuing agricultural research is a recent phenomenon of 10–15 years, and it is rapidly but selectively picking up. Studies have shown that factors like lack of ability to enable the regulatory environment, public-sector crowding-out effects, poor policy incentives, distrust in the public domain of large firms, obstructionist administration, and so on are responsible for poor participation of the private sector in agricultural research (Pray and Nagarajan 2012).

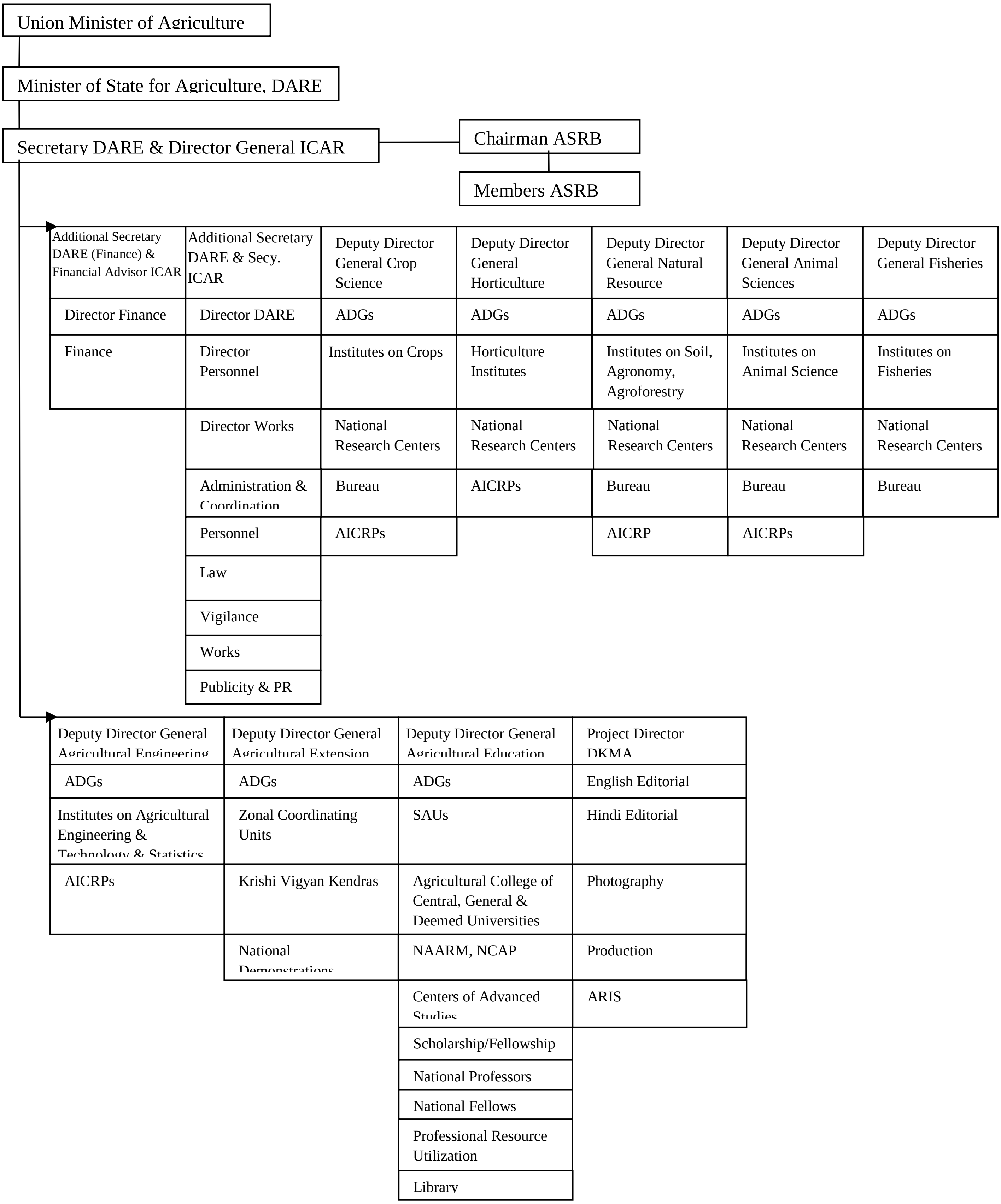
At the center of the public sector, the main ministry dealing with agricultural research is the Ministry of Agriculture, though some support to agricultural research is also provided by the Ministries of Science and Technology and they Ministry of Health and Family Welfare. In the Ministry of Agriculture, the Department of Agricultural Research and Education (DARE) through ICAR has the mandate for coordinating, guiding, and managing research, education, and frontline extension in agriculture, including horticulture, animal sciences, and fisheries in the country. At the state level, the SAUs are responsible mainly for agricultural research, education, and frontline extension. To date, 97 agricultural research institutions of different types and disciplines are under ICAR, and 56 SAUs are spread across length and breadth of the country (Appendixes 1 and 2). The major components of NARS, namely ICAR and SAUs, employ 4,800 and 21,000 scientists, respectively, making a total research commitment of only 5,059 research staff in the ICAR and other government bodies, and around 6,158 in the SAUs in terms of full-time equivalents (Stads and Rahija 2012). Significantly, the extent of centralization attained today within NARS generally ensures that almost all of the experiences of ICAR are also reflected in or have impacts on SAUs. But the dichotomy between states and the central government in respect of planning and implementation of agricultural development schemes including AR4D is a matter of continuing concern. The dual control on SAUs by the state on administrative matters and ICAR on technical matters creates stress on SAUs for compliance of instructions from both sides, and in the process, the performance of SAUs becomes variable. The record of compliance of rules and guidelines in the implementation of central schemes by the states and their institutions is highly variable based on political setup, capacity, interest, resources position, and so on in the state. The central government can only inquire and advise the states on the implementation of the central schemes, but not enforce or insist on guidelines, norms, and procedures.

The main structural issues relating to public-sector research, mainly ICAR and SAUs, which often dominate the debate on improving the performance of NARS, include the structure of ICAR, the major partner in the NARS; the role and relations between ICAR and SAUs, ICAR and SAUs with the government, bureaucracy (administration and finance) in the science system itself (ICAR and SAUs) and the public sector and private sector; and political economy factors.

3.2 The Structure of ICAR

An organizational chart of ICAR with all its complexity is given in Figure 3.1. Two terms regarding the structure of ICAR and its headquarters are often discussed: *bureaucracy* (government by officials) and *technocracy* (government by technical experts).

Figure 3.1—Organizational chart of the Indian Council of Agricultural Research (ICAR) and the Department of Agricultural Research and Education (DARE)



Source: www.icar.nic.in

Notes: ADG, assistant director general; AICRP, All India Coordinated Research Project; ARIS, Agricultural Research Information System; ASRB, Agricultural Scientists Recruitment Board; DKMA, Directorate of Knowledge Management in Agriculture; NAARM, National Academy of Agricultural Research Management; NCAP, National Center for Agricultural Economics & Policy Research; SAU, state agricultural university.

Bureaucracy. It is important to look at the ICAR headquarters from the point of view of its basic job of facilitation of agricultural research, a technical function in the country. ICAR is a premier national agricultural research organization established as a society with the mandate of agricultural research, education, and frontline extension. Surprisingly, it was organized on a secretariat pattern even before becoming a part of DARE as a typical government department with an administrative function, an official mindset of functionaries, and processes and features. The fundamental weakness of the system is that its workforce is not clear on whether they are officers or scientists in performing their duties. The workforce, working style, and mindset in DARE further contribute to this confusion. It would be better that the officers in DARE and administrative and finance workforce in ICAR realize their main role as that of serving science rather than bureaucracy. The present relationship of the headquarters with the institute is more akin to that of a secretariat seeking to control subordinate offices (ICAR 2005). ICAR's work ethos continues to copy a government department, with its institutes controlled by the headquarters on all crucial matters. Its format of governance can best be described as "limited autonomy" and "controlled decentralization" (NAAS 2002). Further, it can be seen that most research programs are currently organized with a commodity orientation or address scientific issues in a disciplinary manner. Most second-generation problems facing farmers require approaches to be organized in a problem-solving mode. For this to happen, multidisciplinary and multi-institutional research becomes important. Generally, agricultural research has focused on favorable ecologies, and the harsh ecologies have been bypassed, creating a big divide between them. Therefore it is important to focus research on harsh ecologies to mainstream them for development. The Centennial Group (2011) report states that the shortfall between real and field trials points to the public research system's inability to shift from its commodity-based research thrust to the systems approach that focuses on the farm-level problems specific to agroclimatic zones. The Approach Paper to the 12th FYP of the India's Planning Commission (2011a) also states, "Public sector technology generation often fails to take into account farmers' needs, perceptions, and location specific conditions for each crop, leading to significant gaps between the varieties released by public sector institutions and the number of varieties actually used by the farmers. It is unfortunate that we have data on release of varieties but not on area under them over the years." There is a need to increasingly reorient and adopt a systems perspective in research with enough emphasis on institutional arrangements including linkages at different levels and strengthening the social science component of research and integration at different levels in solving the problems that affect farmers, particularly small farmers and women. On the basis of recommendations of review committees, over the years ICAR attempted to integrate the administrative and technical functions for expeditious disposal of queries received from the institutions through a single-window approach under a subject-matter division headed by a deputy director general. But in practice this purpose is defeated and the common feeling in the institutes is that the system is overly bureaucratic and perceived to be involving itself in micromanagement of the institutes. It would be better for ICAR to shed, de-emphasize, or decentralize the maintenance functions and become more of a think tank for AR4D in the country.

Technocracy. The Swaminathan Task Force (India, Planning Commission 2005) recommended that the ICAR headquarters be a compact technical body engaged in the development of research visioning, strategies, and progress monitoring and evaluation. Mashelkar Committee (ICAR 2005) states, “In a research organization of the size, spread, magnitude and diversity of the ICAR, the role of the HQ is almost akin to that of the brain in the body system. The quality of agricultural research and education in the country depends on the intellectual and organizational leadership provided by the ICAR headquarters.” The role of different deputy director generals may need to be as advisor or member of a think tank to the director general in respective subject matter areas and fields of experience in the council. The society model of governance was chosen for the council to give it the operational freedom and flexibility across the system to function as a science organization. But as long as it continues to operate by applying government rules and procedures ipso facto for its operations, it won’t be able to come out of civil service bureaucracy. Mutatis mutandis facility of making necessary alterations in instruments of governance remains mostly unutilized in ICAR, unlike other public research institutions like the Council of Scientific and Industrial Research (CSIR), which have taken advantage of this facility to ensure a relatively higher degree of devolution of powers to the institutes and scientists (NAAS 2002). Although ICAR has tried to decentralize administration, the institutes still do not have the desired level of freedom and flexibility (ICAR 2005). Sometimes institutes are not in compliance with the many decentralized rules and procedures because of the scare of increasing vigilance and lack of knowledge, confidence, and understanding of administrative and financial rules and procedures.

3.3 The Role and Relations with the Partners

ICAR and SAUs. One of dimensions that defines NARS relates to the role of the center (ICAR) and the states (SAUs). In discharging its role as a national coordinating agency in agricultural research, ICAR has established linkages not only with national organizations like the Planning Commission, Department of Science and Technology, CSIR, Indian Council of Medical Research, Indian Council Social Science Research, Department of Atomic Energy, University Grants Commission, and others, but also with international research organizations and institutes, Food and Agriculture Organization of the United Nations (FAO), United Nations Development Programme (UNDP), World Bank, International Development Association, Asian Development Bank (ADB), and others. But these linkages, particularly with sister science organizations CSIR, Department of Biotechnology, and others, are not robust as yet.

At the state level, the counterpart organization with more or less the same mandate is SAU. Over the years, ICAR has played the promotional role by serving as University Grants Commission in providing development grants (which form about 10 to 30 percent of the total resources of SAUs) to SAUs for strengthening agricultural education in the states. It also provides research funding support to SAUs through All India Coordinated Research Projects (AICRPs), network projects and externally aided projects (EAPs) and funding support to frontline extension through Krishi Vigyan Kendras (KVKs). These supports are considered very valuable by SAUs for strengthening state-of-the-art research infrastructure and meeting the research contingency and educational expenditure, because SAUs are generally deficient of funding support by the State. Jha (2002) states that central funds will always be critical for state research, at least in the short and medium term, because the limited size of their clientele apart from other reasons will always make states underinvest in agricultural research and education.

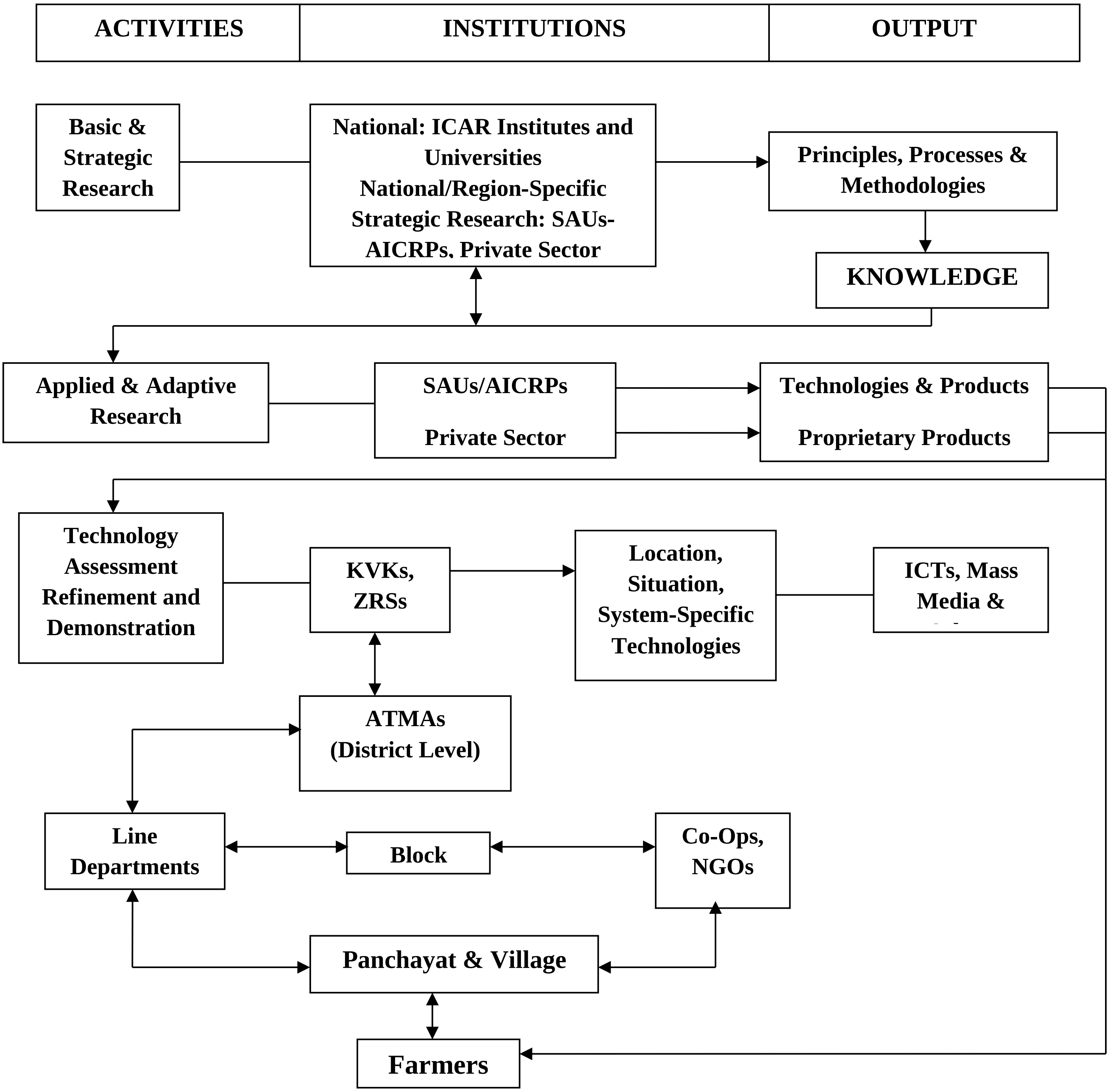
On account of the financial support by ICAR, SAUs have maintained a very cordial, but informal or voluntary relationship with ICAR. Generally, regarding research initiatives, the SAUs meekly follow the lead provided by ICAR. This arrangement may need to change now to match with the changing scenario of the sector in the State, emerging new actors on the scene, and the overall deterioration of the scientific and institutional backstopping for research in the states. The dominant role of ICAR in the future may be to help create strong, competitive, adjunct institutions like SAUs at the state and zonal levels, some even sharing national research responsibilities in addition to their own localized mandates. This may also be an answer to the suggestion of rationalization, integration, and consolidation of ICAR institutes, as ICAR has become too big an organization. It is reported that states now contribute nearly half of the total public expenditure on research and education, but their share in total manpower employed exceeds 65 percent. This implies high disparity in support per scientist between the state and the central sectors. This is a major concern (Jha and Kumar 2005). Another related concern is that the manpower in SAUs has been reducing steeply, while the number of universities is increasing on subject matter or disciplinary basis. This suggests what is also known as a fact, that the new units are created largely out of the existing universities and are being manned through redeployment, seriously affecting research and educational standards. Yet another concern is the vey skewed distribution of scientists among institutions as revealed by the fact that more than 82 percent of institutions account for only 14.3 percent of the scientific manpower (Jha and Kumar 2005).

Another debated issue is whether to focus on basic and strategic upstream research or on applied, adaptive, and anticipatory research by ICAR and SAUs. Several committees have suggested that national-level basic, strategic, and anticipatory research be carried out by ICAR institutions (with substantial economies of size); that applied and adaptive research, management of national research networks (to promote spillovers) and region-specific strategic research be carried out by SAUs, AICRPs, and the private sector (ICAR 1988, 2005; Byerlee and Alex 1998).

Some of the stress points that have emerged between ICAR and SAUs in the otherwise cordial relationship include not following the revised Model Act, the establishment of several disciplinary-based universities within the state without the knowledge of ICAR while also pressuring ICAR for additional development grants to support them, overplaying the research role more than the education and frontline extension role, failing to maintain education and research standards on account of not filling vacancies on time, diversion of development grants to other heads, and others. These stress points are mainly arising because of ICAR’s lack of authority over SAUs to strictly enforce the Model Act and monitor the progress made. For this, ICAR is discussing the option of formalizing its informal relationship with SAUs with an act of Parliament like the Veterinary Council of India Act of 1984, where it operates under the aegis of the Ministry of Agriculture and derives its funding from the same. It is even suggested that 25 percent of the faculty of SAUs be selected on a national basis particularly to induct merit and to avoid the intensive inbreeding problem in the SAUs.

As per the mandate of ICAR, technology assessment, refinement, and demonstration (frontline extension) must be carried out by Krishi Vijyan Kendras (KVKs) under ICAR and by zonal research stations under SAUs in collaboration with Agricultural Technology Management Agencies (ATMAs) under India’s Department of Agriculture and Cooperation. In view of experiences and suggestions of several committees, including reports of Quinquennial Review Teams, the suggested framework by ICAR for such an arrangement is given in Figure 3.2, which provides in a flow diagram an ideal technology development and delivery system with activities, institutions or partners, and output. Use of this framework can particularly enhance the functional relationship and synergy between KVKs and ATMAs, and also other development departments, provided more attention is given to increase manpower trained in all agriculture and allied sectors. These sectors would include modern information and communication technologies (ICTs) with needed mobility and electronic connectivity to reach inaccessible areas and farmers to provide knowledge along with an adequate and effective input and service delivery system.

Figure 3.2—A framework for technology development and delivery



Outcome

Enhanced Profitability; Productivity; Sustainability; Livelihood Security; Employment Generation; Competitiveness; and Food, Nutrition & Environment Security

Source: www.icar.nic.in
Notes: AICRP, All India Coordinated Research Project; ATMA, Agricultural Technology Management Agency; ICAR, Indian Council of Agricultural Research; ICT, information and communication technology; KVK, Krishi Vigyan Kendra; NGO, nongovernmental organization; SAU, state agricultural university; ZRS, zonal research station.

An important point of significance, but still unknown or without attention, is the percent allocation of resources or emphasis on research, education, and extension in the NARS. As for the extension function, the argument is that NARS is mandated to frontline extension, not public extension. The public extension system has almost ceased to remain effective, and therefore the pressure on the frontline extension system of NARS is mounting. Whether NARS can continue to ignore this development needs debate and innovative decision. At the same time, the capacity (financial and human resource) to undertake the public extension function is simply not within NARS. It is reported that for every one unit of investment in research, two to three times more investment is required to achieve widespread adoption of technologies produced by that research. Thus extension is a highly resource-intensive activity (EIARD 2011).

Regarding commercialization of technologies, over a period of time, NARS has developed a large number of technologies to benefit the small farmers; farmer entrepreneurs; unorganized cottage and agro-industries; medium and large commercial farmers; and entrepreneurs involved in production, processing, and marketing of inputs, products, and by-products spread across the country. As far back as 1994, ICAR put in place the framework for partnership, resource generation, training, consultancy, contract research, contract services, and incentives and rewards (ICAR 2004). ICAR also has a publication entitled *Technologies for Commercialization and Adoption* and has also framed intellectual property rights (IPR) rules compatible with such laws in the country (ICAR 2009). The council is also spreading IPR literacy across the system. The intellectual property and technology management activities in the ICAR are taken up through a decentralized intellectual property management mechanism. The diverse set of technologies generated at the research institutions has been evaluated and categorized by ICAR on the basis of various parameters. Depending on the core strengths, the institutes have entered into partnerships through licensing, agreements, or memorandums of agreement or understanding for technology transfer, commercialization, consultancy, contract research, certification of services, and so on.

ICAR and its institutes regularly organize meetings to augment NARS's relationship with agri-industry of all kinds and scale and to have a better client orientation (ICAR 2012). Further, during 2011, ICAR established Agri Innovate India, a company owned by the India's DARE. This company is mandated to promote the spread of research and development (R&D) outcomes through IPR protection, commercialization, and forging partnerships both in the country and outside the country (India, Department of Agriculture and Cooperation 2012). Such an initiative gives ICAR greater autonomy and flexibility to adopt better business practices for financial and personnel management (including setting salary levels)—practices that are more conducive to attracting high-quality scientists and utilizing them effectively (Byerlee and Alex 1998). The technology commercialization system at SAUs is highly varying and needs systematic efforts to frame rules, procedures, and mechanisms.

ICAR/SAUs with Government. Because agriculture deals with basic necessity of food for the general population, any aberration or disruption in food supply and prices will invoke immediate public anger or protest. Usually the public, including the government, holds agriculture responsible, and specifically AR4D. Generally NARS will be in the news for not providing technologies to increase supplies, which affects the image and credibility of NARS as well as the working relationship with and financial support of the government. To a large extent, this shows a failure of NARS to communicate with the government in particular and the public in general: NARS has not realized the gains of technology by properly communicating/disseminating their achievements and gaining the critical support of an effective distribution system. Also contributing are attitude and behavioral differences between scientists and bureaucrats in government, which leads to stress and less trust between them.

The financial and administrative autonomy to ICAR/SAUs is often debated as a major issue. ICAR is a registered society. ICAR was accorded an autonomous society status at the time of reorganization in 1973. The vision for this governing body was that it would function autonomously, free from inelastic regulations as well as government authority. The setting up of DARE with the director general and ICAR also as a full-fledged secretary was designed to achieve fusion of the government authority with functional autonomy so essential to a science organization. A very similar model operates within the Department of Scientific and Industrial Research with the Council of Scientific and Industrial Research (CSIR), which is opined to have derived the fullest advantage of the fusion of government authority and functional autonomy with the framing of independent rules and regulations to meet the requirement. But ICAR has not done this because it has not been able to frame its own rules and procedures. Therefore, institutes under ICAR still have the overhanging culture of a subordinate office within the government of India and do not internalize the strength of the organizational structure of ICAR, a structure that concurrently confers upon it autonomy in science administration and freedom from inelastic regulations and government authority. Thus, several committees including the Mashelkar Committee (ICAR 2005) have recommended the urgent need to frame rules and procedures suitable to ICAR. To give the highest importance to agriculture in the country, the committee recommends that the prime minister of India should be the president of the ICAR society, like the CSIR. At the state level too, the interface between the Department of Agriculture and SAU is under similar stress (Jha 2002). It is time that this issue be sorted out once and for all.

Another issue that crops up often is the respective roles of the science department and the development department in the transfer of technology. For instance, the agricultural department feels that technologies recommended by ICAR and SAUs are not suitable or viable for transfer to farmers, whereas ICAR and SAUs feel that they have perfected and tested the economic viability of technology as per the requirements and that it is the responsibility of the public extension system (agricultural department) to transfer it to farmers. The implementation of the ATMA model by the agricultural department was to strengthen the public extension system at the district and lower levels, but the expected convergence with the KVK system for scientific inputs still has not happened. The recent initiative by the secretaries of the Department of Agriculture and Cooperation and DARE to forge convergence between ATMAs and KVKs has again remained mostly on paper at the administrative level but is not at the functional level.

Scientists and Bureaucrats within the Science System Itself. The scientists need the support of administration and finance from institutes and universities for managing research projects and institutions, particularly in public-sector institutions, where the funding support of government is substantial. Sometimes, by mechanically insisting on use of rules and procedures in administration, procurement, and financial management by administration and finance staff, scientists feel greatly harassed. This is the most common and continuing stress point in the science system for improved performance. The Prime Minister in succession had assured the scientific community that "removing the control of bureaucrats is one pressing reform needed to improve the governance structure of our research and higher education institution" (ISCA 2001). In his address at the Indian Science Congress in Ahmedabad, the successive prime minister also called for ending the "tyranny of bureaucracy" in scientific institutions. The rules and procedures are themselves partly to be blamed because they may be outdated and lack sensitivity to scientists and special requirements of scientific work. The stress is minimal wherever there is better understanding of sensitivities of scientists, the special requirements of scientific work, and the value of scientific achievements by administration and finance staff, and reciprocally, appreciation of the spirit of rules and procedures to maintain accountability to use public funds, and a general awareness about why and how to follow the rules and procedures. Can this happen at both ends?

Public Sector and Private Sector. Another major structural issue that always dominates the debate is the relative role of the public sector and private sector in AR4D. The entry of the private sector in development of agricultural technology in India has been more prominent in the last 10–15 years, subsequent to the liberalization of technology importation and foreign investment that began in 1991. Private-sector research and development was significant, accounting for more than 11 percent of Total Factor Productivity (TFP) growth (Evenson, Pray, and Rosegrant 1999; Pray and Nagarajan 2012). The contribution is reported to have increased to 15 percent as of 2000 (Pal and Byerlee 2003). The entry has been a response to the related phenomenon of the expanding R&D capacity of the private sector that has resulted from a combination of technical advance, improved IPR regime, and a more liberal trade and economic environment. The key reforms that facilitated this public/private–sector partnership (PPP) are the establishment of mechanisms by ICAR to provide its services on a consultancy and contractual basis, making available germplasm and other technology products of ICAR to the private sector at nominal cost, and most recently the framing of IPR and the policy and rules related to commercialization of ICAR technologies. The private sector is selective and prominent in the research of seed, plant protection, fertilizer, farm machinery and equipment, food processing, plant breeding and biotechnology, animal health, poultry, and high-value agriculture. Its presence is minimal in research relating to national resource management (NRM), disadvantaged areas, coarse cereals and millets, and so on. Involvement of the private sector is expected to improve with still better policies of PPP, trust and transparency, information sharing, technical advances associated with biotechnology, clear IPR and regulatory regime, and suitable financial investment and tax incentives from the government (Pray and Nagarajan 2012). However, the responsibility of the public sector in areas that are not of interest to the private sector will continue to be crucial. The principle is that the public sector needs to support but not compete with the private sector. Nongovernmental organizations (NGOs) can focus on smallholders and disadvantaged areas in technology dissemination. The Prime Minister recognizes the critical role of the private sector in agricultural research and states, "While the public sector needs to take the lead we also need much greater private sector investment and involvement in agriculture, particularly in R&D. Indeed, it is unlikely that the goal of 2 percent of AgGDP in research can be achieved unless a significant part of this is financed by the private sector." (IARI, 2012). Hall et al. (2001) outline three types of public/private–sector participation: private distribution of public technologies, private purchase of public research services and technologies, and public–private collaborative research partnerships. In their case studies, they found that patterns of interaction were not as extensive or as effective as the potential would imply. They attributed this failure to historical patterns of institutional development, as well as administrative traditions in public agencies that prevent more effective interaction. They suggested introducing institutional learning as way of remapping roles and relationships within an innovation systems framework, coupled with a more adventurous program of institutional experimentation to give fresh impetus to the reform of public-sector agricultural research in India.

Political Economy Factors. Like everything else in a democracy, politics affects research also (Jha 2002). It provides signals and it acts as a balance. It also plays influence peddling. An important role for the research system is to keep the polity analytically informed. NARS has extremely weak linkages here. In the absence of clear-cut policy for defining the boundaries of political interference, politics introduces distortions. NARS has to build a lobby to generate political support and bring demand pressure to bear more strongly not only on the research agenda but also on policymakers and policymaking, that is, the people who allocate funds to research.

3.4 Enabling Environment to Science: Institutional (Process) Issues

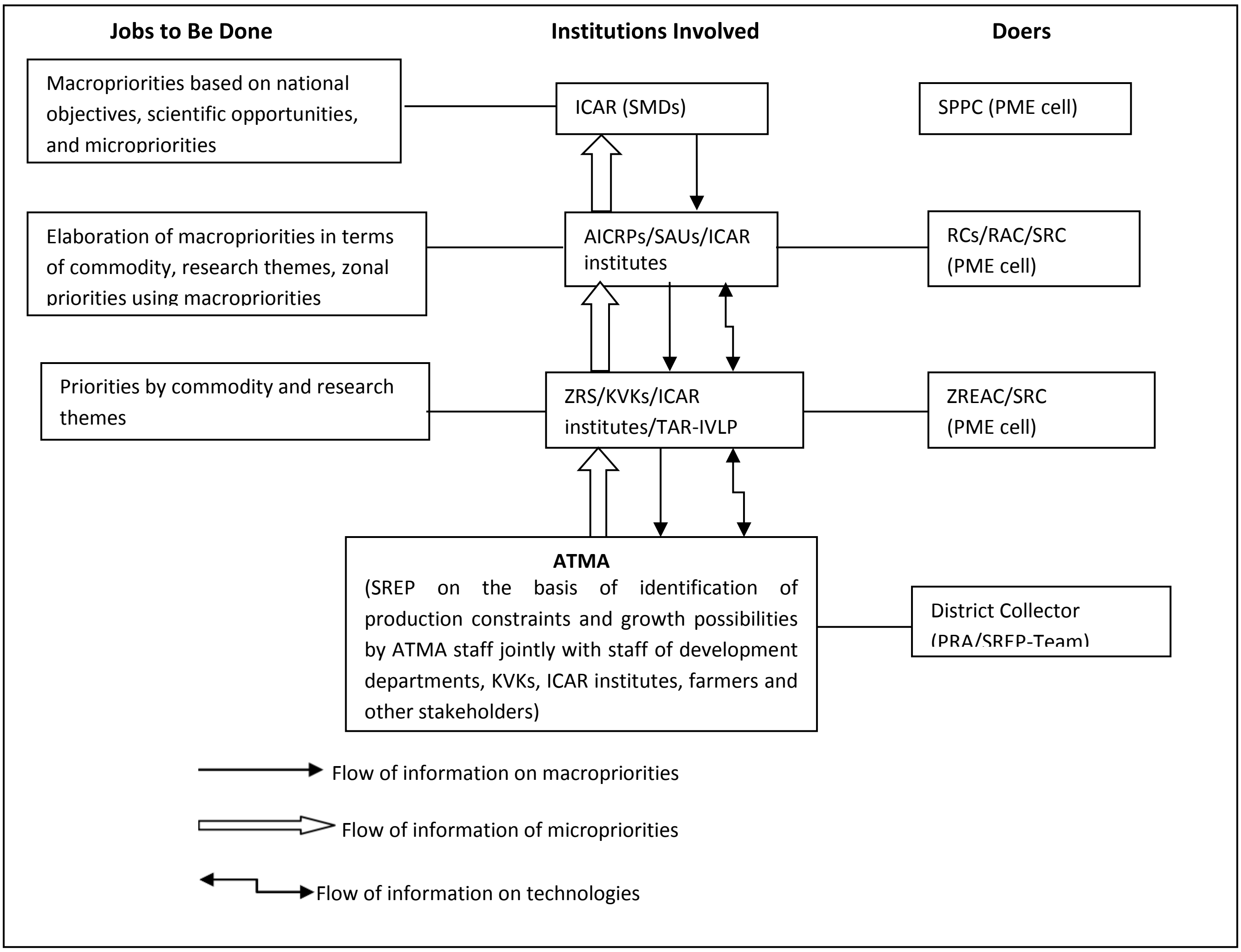
Some of the process issues that are important to impart efficiency and relevance of the work done by NARS relate to priority setting and monitoring and evaluation (PME), administration and financial reforms, human resource development (HRD), and partnership and linkages. A brief account of each follows.

3.4.1 Priority Setting and Monitoring and Evaluation

PME research is a best practice to promote accountability in the system, one that is recognized globally to assist research managers for focused allocation of resources to contribute to research efficiency, relevance, and accountability. Institutional Learning and Change Initiative (ILAC) Brief 24 (ILAC 2010) states that accountability for an R&D organization comprises the processes and practices that an organization puts in place to keep all the stakeholders informed, to take into account and balance their interests, and to ensure equitable responses to their concerns. ICAR has pursued informal or subjective priority-setting exercises through mechanisms of Quinquennial Review Teams, Institute Research Council, Institute Management Committee, Research Advisory Committee, and others, that use judgment of knowledgeable scientists regarding current and emerging problems, prospects, and opportunities in science (Jha and Kumar 2005). Generally ICAR's accountability system is loaded more with input accounting and auditing procedures (as normally with all government departments) and less with output and outcome evaluation systems (NAAS 2002). However, some evaluations have shown that these mechanisms and processes have been quite efficient in generating high rates of return on research investments in the past (Mruthyunjaya and Ranjitha 1998). Such mechanisms are very weak in SAUs. However, to address emerging complex challenges, formal, objective approaches were introduced through pilots under the National Agricultural Technology Project (NATP) and now the National Agricultural Innovation Project (NAIP). The idea is not to replace scientific judgment but to augment, organize, and institutionalize improved decision-making mechanisms in NARS. Independent efforts were made by the National Center for Agricultural Economics and Policy Research (NCAP), the Asia Pacific Association of Agricultural Research Institutions (APAARI), and the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) to identify research priorities in India from time to time (Mruthyunjaya and Kumar 2010). Although the approach of objective research prioritization is well appreciated, these efforts mostly remained as academic, normative allocation exercises, with no major institutional initiative so far to integrate these in the planning process. The idea of research prioritization is yet to be institutionalized in the NARS and also is not explicitly figured in the allocation plans for national resources. Even the 12th FYP exercise for agricultural research has remained traditional in approach, focusing on research gaps and incremental investment needs based on scientists' and other experts' perception regarding these parameters as well as institutional strengths and weaknesses (Jha and Kumar 2005). One can easily see the sectoral imbalances in allocation of resources particularly in livestock and fisheries, where contributions have increased in recent years. Similarly, the growing importance of postharvest management (PHM) social sciences is not adequately reflected in the budget allocations. It is necessary to step beyond isolated analytical exercises and invest in the creation of national systems and capacity to integrate these exercises into the routines of the budget process. Reviews of public expenditure are, after all, useful only to the extent to which they feed into the setting of policy priorities and allocation of resources (ODI 2007). Recently ICAR decided to establish PME cells in each one of its institutions to pursue research prioritization, monitoring, and evaluation. But the available details of the decision suggest that the expected professionalism, modalities, and spirit of PME is still missing in the official order and the initiative may not achieve the intended objective of institutionalizing the PME culture and practice in the NARS. The resource allocation profile has been criticized for showing persistent bias toward commodities and regions and neglect of evolving market opportunities, and for other critical weaknesses.

Ideally, with the change in emphasis toward a location-specific farming system based on farmer priorities, the research prioritization should follow the bottom-up approach, with the microlevel and macrolevel priorities forming a circular continuum. But it is generally felt that the microlevel priorities are not systematically and transparently integrated into macrolevel priorities (which are largely commodity and discipline oriented), and thus a disconnect exists between the two. To converge the micro- and macropriorities for a proper alignment and continuous linkage from strategic to applied research, the strategy, model, and action suggested (Mruthyunjaya et al. 2003) are shown in Figure 3.3. The policy changes needed to put the model into action in NARS are also elaborated in Mruthyunjaya et al. (2003) with an illustration.

Figure 3.3—Schematic representation of convergence between the micro- and macrolevel priority setting



Source: Mruthyunjaya et.al. 2003

Notes: AICRP, All India Coordinated Research Project; ATMA, Agricultural Technology Management Agency; ICAR, Indian Council of Agricultural Research; KVK, Krishi Vigyan Kendra; PME, priority setting, monitoring, and evaluation; PRA, participatory rural appraisal; RAC, Research Advisory Committee; RC, regional center; SAU, state agricultural university; SMD, Subject Matter Division ; SPPC, Strategic Planning and program Cell; SRC, Staff Research Council; SRFP ,Strategic Research and Extension Plan ; TAR-IVLP, Technology Assessment and Refinement–Institute Village Lingake Programme; ZREAC, Zonal Research and Extension Advisory Council; ZRS, Zonal Research Station.

Rajeswari (1999) reported, "If Indian researchers manage to institutionalize a rigorous planning, monitoring and evaluation process in scientific research they have won an historic battle with the bureaucratic imperatives of science." She concluded that unless stringent evaluations are introduced in ICAR, the professionalization of agricultural research in India will remain incomplete and bureaucracy will continue to point fingers toward the research system. The systematic impact assessment efforts are almost negligible in NARS. The Swaminathan Committee (India, Planning

Commission 2005) observes, “Resisting change in institutional and management structures will be a formula for increasing farmers’ distress.”

A clear view should exist on the means of measuring and enhancing the effectiveness of AR4D. Impact assessments and evaluations are important to (a) enhance the development impact of agricultural research investments for poor people, (b) provide information on the returns to investments in AR4D, (c) derive strategic and programmatic lessons for future investments in AR4D, and (d) provide information for use in public awareness work. Points to be kept in view are that the complex social, economic, and political dimensions of pro-poor innovation need to be recognized and addressed; that the goal is to establish plausible links between research investments and development impacts; and that policy design, learning and public awareness, and stakeholder interests and intentions need to be assessed (EIARD 2007; Joshi et al. 2005).

It is important that the system operate on a project mode for its research programs and funding like that in CSIR, where the entire research portfolio of the institute is projected. ICAR tried to introduce project-based budgeting earlier but did not succeed in making it a reality. The idea needs to be implemented with freedom, flexibility, and accountability to principal investigators of the project. It is welcome that ICAR is trying to strengthen the capacity of monitoring through quarterly progress reports of the institutes, half-yearly progress reports of institutes and all scientists, and now half-yearly performance monitoring reports of institutes and all scientists, which are also online now. But the system is far from perfect in that standard instructions are not readily available to scientists to complete the reports and that scientists are not clear about the use of the reports and the relationship between monitoring reports and annual assessment reports of scientists. Notwithstanding the automation of the system, the size of the system disables the management from critically analyzing such reports and using them for improvement of the system (Hall et al. 2001).

If ICAR is to remain as a global leader in agricultural science, it has to invest in visioning and technology foresight. ICAR made a beginning in preparing the Perspective Plans for its institutes initially and documents on Vision 2020, 2025, and 2030 (ICAR 2011) for its institutes and ICAR as a whole in the recent past. No doubt these exercises have sensitized the system about the need and format of the effort, but still there is a long way to go in terms of a professional approach to prepare them and use them optimally and appropriately where they have to be used. The plans of the council to establish a Technology Foresight Cell during the 12th FYP and the very recent initiative to develop ICAR Vision 2050 are welcome developments.

3.4.2 Administration and Financial Reforms (Organization and Management Reforms)

By the early 1990s, for reasons of size alone, ICAR was already facing severe financial and operational problems (Mruthyunjaya and Ranjitha 1998; Hall et al. 2001). In the context of changing complex challenges, ICAR has to do business differently and in a more down-to-earth and professional manner. It has to create a new identity and define new roles and paradigms. Over the years, ICAR has realized that investment in O&M reforms is as important as investment in research, as it has strong bearings on the work environment and culture, efficiency of the organization, and productivity of science and its growth. Maintaining a high-quality system through appropriate institutional arrangements, management reforms, incentives and rewards, training, funding mechanisms, interface with stakeholders and particularly the private sector, and increased information and communication technology are important not only to become locally relevant but also globally competitive. Stakeholders are aware that the system should undergo change and take steps to usher in the change process. But the impact of the reforms has been less than expected. In fact, no systematic efforts have been made to measure the impact. The scale of reforms in an organization such as ICAR makes this a formidable task, both time consuming and costly (Paroda and Mruthyunjaya 1998; Mruthyunjaya and Pal 1999; Hall et al. 2001). To ensure a smooth and painless change process, it is important to recognize that change takes time, requires commitment at the highest level, and should be as much as necessary and as little as possible and the least disruptive (Paroda 2002). Maintaining the status quo is not in the interest of those concerned and involves more and more people to build a critical mass to make the change process a success.

Research is a resource-intensive activity—it requires high-quality human and other resources. It is therefore expensive. It is a highly uncertain process, and failures heavily outnumber successes. Research also has a long gestation period. Lack of appreciation for these basic attributes leads to three problems in terms of support for publicly funded agricultural research. First, policymakers underinvest in research, preferring shorter and more certain options. Second, since expected benefits are fuzzy, because of uncertainties, funding decisions often tend to be subjective. Third, fund managers often err in routine evaluation criteria to judge research investments and also in losing patience with a long and uncertain gestation period (Jha 2002). Expenditure norms for research have to be different.

3.4.3 Agricultural Education and Human Resource Development

India has achieved spectacular agricultural growth since 1966. Apart from government policies and high receptivity of the farming community, the seed of success was planted by establishing institutions of higher agricultural education (Appendixes 1 and 2). These institutes have embraced education, research, and extension education as integral to their functioning and have contributed a great deal in propelling agricultural growth in the country.

The challenges in agricultural education include maintaining quality, inadequate state funding, depleted faculty strength, inadequate faculty development programs, lack of competence of existing faculty in new and emerging areas, extensive inbreeding in faculty, lack of modern infrastructure for education and research, establishment of new sectoral or disciplinary-based SAUs and new colleges without matching resources, lack of integration of agricultural education with job creation, inadequate revision of course curricula for producing human resource personnel that are professional service providers and address the demand of client groups, and so on. Stads and Rahija (2012) reported that the number of agricultural researchers in India has fallen by 8 percent since the new millennium, largely as a result of declining capacity in the SAUs (about 41 percent of the sanctioned posts are remaining vacant in SAUs). Singh and Alka (2011) reported that the strength of manpower has not kept pace with the growth in number of institutions, universities, and colleges and that the number of occupied faculty positions in several agricultural universities has markedly dwindled, besides suffering from inbreeding, aging, and declining skills. It is even reported that in some SAUs the medium of instruction is the language of the state, which is creating problems for international students and students of other states of India. It is time to review the agricultural education system in the country after experiencing more than 50 years of the land-grant model of education in India. The model is completely reoriented in the United States and other countries to suit the changing need. India needs to review and put in place a new agricultural education system incorporating the experiences and future needs. The proposed Agricultural Higher Education Project with the assistance of World Bank in India should aim to overcome the deficiencies and usher in a new system.

One of the important dimensions of building competent human resources is training and capacity building, and a basic function of any organization to continuously upgrade the knowledge and skill of the workforce and groom leadership in the organization. The council has created an in-house capacity by establishing a very unique institution called National Academy of Agricultural Research Management (NAARM) in 1976 to impart in-service training to its workforce, groom leadership, and also conduct research on agricultural research management issues and advise the council from time to time. The academy has evolved over the years but is still struggling to fulfill its mandate. The council also deputes workforce for training in India and even abroad; in fact, every institute has a separate budget for HRD and training. For most, the training budget is unused or only partially used on account of an inflexible and uncertain deputation policy and the rules and procedures. For some, there is no definite training plan and no plan to better utilize the trained workforce after the training. Finding good and inspiring leaders and meticulous succession planning of leaders should be a visionary exercise of any learning organization. The dearth of quality, competent, innovative leaders who can inspire, ignite, change mind-sets, enhance the quality of the academic environment, build teams, and ensure efficient professionalism in the workforce of the system is a major worry to the NARS. A preliminary study by NAARM has reported that the leadership effectiveness at different levels in NARS is only average to moderate with few exceptions (NAARM and TAAS 2010). NAARM and TASS (2010), among others, has also suggested that ICAR should have in place its own HRD policy, appoint a full-time HRD director as soon as possible, and improve recruiting of research managers (at the director level and above) by following a two-tier system rather than by selection based on a short interview, which is done presently and may be satisfactory for selection of scientists. In the context of national demand and a changing global scenario, identifying and developing quality human resources required at various levels is of strategic importance. ICAR has made attempts to assess the human resource requirements in agriculture and allied sectors in advance so as to put development of agricultural human capacity development on a rational footing (NAARM and IAMR 2012). How these estimates are used for developing the 12th FYP for agricultural human resource is very important.

Personnel Policy. The quality of scientific manpower has a direct bearing on the research output of the organization. The policies governing recruitment, training, placement, and motivation of scientists therefore are important. The Agricultural Research Service was formed in 1975 as an all-India service. All appointments were to be made at the entry level on the basis of a written examination conducted by Agricultural Scientists Recruitment Board (ASRB). Lateral entry was also possible. The Agricultural Research Service was formed to replace the prevalent post-centered system with a scientist-oriented system. Promotion in the service was made irrespective of occurrence of vacancies on the basis of rigorous assessment five times each year. But ICAR has now opted for the University Grants Commission procedure because the assessment procedure as practiced in the system failed to make a distinction between performers and nonperformers. ICAR has introduced the scorecard system to overcome the drawbacks, but the system is highly criticized. It is also important that the government exempt scientific establishments like ICAR from such rules as filling up only one-third of the vacancies every year, vacancies for more than a year are deemed as abolished, and so on. As a result of the restricted recruitment policy for about 15 years to downsize the public system, higher average age and higher attrition rate is observed in the public research system, adversely affecting scientific productivity in the NARS (Jha and Kumar 2005). Another development is that there is flight of talent from ICAR, which is reflected in the limited number of scientists appearing in ASRB interviews for direct recruitment. As in CSIR, to meet the immediate and short time requirements of scientific staff, ICAR has to employ a quick-hire system, where the director general is competent to hire eligible scientists (ICAR 2005; India, Planning Commission 2005). In view of restrictions on recruitment at the research assistant level, institutions may be permitted to hire qualified need-based research associates to support scientists in projects. This practice, allowed under NAIP, immensely contributed to the smooth functioning of the projects and realizing expected results. Another step to be aggressively promoted relates to two-way mobility of scientists between ICAR institutes, SAUs, the private sector, other national institutes, and Consultative Group Centers (Mashelkar Committee). One more stress point between ICAR and DARE pertains to the foreign deputation policy of the workforce. As a part of stable policy, foreign travel proposal of scientists may be approved by the director general of ICAR. The proposals of foreign travel of the directors and above officers may be approved by the agriculture minister (ICAR 2005).

Another concern that needs attention relates to the distorted cadre structure and placement of scientists in the NARS. Jha and Kumar (2005) report that the present cadre structure for the ICAR/SAU system has become relatively top-heavy against the conventionally ideal ratio of 5:2:1 with respect to assistant professor, associate professor, and professor. It has been argued that if this is not corrected, the overall productivity of public systems will decline (Jha and Kumar 2005). Thus, a recruitment rate in the public system has to be raised and younger scientists need to be recruited to maintain and increase research productivity. Similarly, pro-gender bias needs to be improved.

Incentives and Awards. ICAR has a good tradition of conferring awards for meritorious work of its workforce every year. Over the years, the number of awards has increased not only to cover new areas of work but also in the number of awards. During 2011, 85 awards were conferred under 17 different categories (ICAR 2012). ICAR has to give freedom to the directors to use the resources mobilized to strengthen the research capacity. This will act as an incentive to mobilize resources through commercialization of technologies, products, and services.

Communication and Publicity. ICAR has a Directorate of Knowledge Management in Agriculture (DKMA) that works as the communication arm of the ICAR and is responsible for delivery of information and knowledge generated by the network of ICAR and its institutions. The DKMA addresses its mandate through the Publications and Information Unit, Agricultural Knowledge Management Unit, and Public Relations Unit. It publishes professional journals and popular journals. Besides mobilizing mass media support for sharing agri-information, the DKMA is also covering news and disseminating information through print and electronic media. One of the observations made on DKMA activities is that they need more professionalization and reach.

Partnership and Linkages. In recent years, working in partnership has become commonplace for organizations throughout the world as a means of addressing complex economic, environmental, social, and technological problems. It involves multiorganizational partnerships (including, for example, networks, alliances, and consortia). It also frequently involves end users, including farmers, community groups, or market agents, in research or activities designed to foster innovation. Forms of working across organizational boundaries that were previously referred to as outreach, regional research, networking, or consortia are now commonly labeled *partnerships*. The role of research in society requires successful dialogue and cooperation between those who produce knowledge and those who use it (ILAC 2008). A multistakeholder engagement is suggested. But a multistakeholder collaboration is not a meeting; it is a substantial effort to tackle and solve a difficult problem. It is a process and not an event. Generally, multistakeholder engagements happen at the planning level but remain ineffective at the implementation and impact level. The international cooperation in ICAR/DARE has been operating through memorandums of understanding and work plans signed with the foreign countries and international organizations. Under the work plans, many collaborative projects, technology developments, evaluations and promotions, visits, trainings, consultancies, organizing conferences and workshops, exchange of materials, and so on are covered. However, the monitoring and evaluation of such efforts is weak in the system.

Balancing Agendas. India is facing an ever-expanding range of new research and policy agendas, and a "one size fits all" type of agricultural research organization found in some other countries is not appropriate (Hall, Clark, and Sulaiman 2000). Capacity needs to be developed in frontier sciences, while also supporting adaptive research for traditional and subsistence sectors. Other needs are to support but not compete with the private sector; to support competitiveness in global markets, but not to displace small-scale producers; to increase investment in genetic enhancement versus conservation agriculture; to enhance investment in technology generation versus technology dissemination; to invest more in production or postharvest management; and to enhance food production or care more for food safety and quality, among others. All these diverse and competing agendas need to be achieved without losing sight of either the old agenda of increasing food production or the new agendas and indicators of efficiency, profitability, employment, equity, gender, poverty, and sustainability. The major research tasks that relate to yield are sustaining present yields, closing the yield gap, and raising the yield ceiling. Plucknett (1993) observed that each country, both developed and developing, should have a strategy to carry out research to satisfy these three yield needs, and unless they are carried out successfully, yield performance may suffer and the effort to reduce investments in productivity research to make way for increased research on natural resources is an unwise move. Plucknett feels that productivity research must not be allowed to slip back in pace or competence. The only option to balance the agendas is cooperation and collaboration among all the stakeholders across the globe to share knowledge and resources. The conditions of success in this battle of balancing agendas include willingness at the top level, higher capacity and commitment of the scientific community, better governance of scientific organizations, improved scientific infrastructure, national and international partnership, better funding mechanisms, and enabling institutions and policies. The proposed Vision 2050 of ICAR clearly identifies three future scenarios of ICAR: wither away, in the shell, and on the voyage. The decision of ICAR to address the points raised in the report will decide the future scenario (Chand 2012)

3.3 Enabling Environment to Science: Funding Issues

Following a period of rapid growth in the 1970s, funding has decreased sharply since the 1990s, as well as severe restrictions in operating costs in agricultural research in many countries, combined with O&M problems in many research systems like top-heavy bureaucracy, centralization of decision making, and lack of incentives for the innovation process so essential for research (Byerlee and Alex 1998; Pal and Byerlee 2003; Singh, R.B. 2011). Important changes in the technology for research itself, especially the new biotechnologies and informational technologies, are raising new issues in organizing NARS, related to economies of scale, international collaboration, and public–private linkages. Aid to agriculture has stagnated or declined since the early 1980s. Official development assistance (ODA) to the agricultural sector in general and AR4D decreased in real terms by nearly half between 1980 and 2005, despite an increase of 250 percent in total ODA commitments over the same period (ODI 2007). South Asia has the largest concentration of poor and hungry in the world, even higher than Sub-Saharan Africa. But the investment by the national governments and the donors has not matched the need in South Asia, and therefore it needs immediate correction. India's public spending in AR4D increased from $929 million in public/private–sector partnership (PPP) funding in 1996 to $2,276 million PPP in 2009 (in 2005 constant prices; Stads and Rahija 2012). It is a fact that India is spending only 0.5 percent of agricultural GDP on agricultural research and education. Jha (2002) reports, "If one takes into account ground realities (lack of operational funds, old capital stock, no increment in scientific manpower for quite some time, the high cost of frontier science research to create a globally competitive research system, the need to expand research to neglected commodities and areas, financial crises in states) there is a strong case for raising funding to at least one percent level in the 10th FYP". India's 12th Five-Year Plan (2012–2017) has set an AR4D intensity target of 1 percent of agricultural GDP (Stads and Rahija 2012). Given the current low-intensity ratio in India and other South Asian countries as compared with even other developing countries like China and Brazil, AR4D spending would need to triple or quadruple in the coming years. Bientema and Stads (2008) observed that sustainable financial and political support for agricultural R&D is crucial, as is the creation of attractive investment climates for private investors, if the challenges of sustainable economic and social development facing the developing countries are to be met.

Public research organizations in India are beginning to diversify funding sources to make up the deficit in annual budget outlays and to develop more market-driven mechanisms for funding research and extension. As stated earlier, ICAR has already initiated measures to allow sales of research products and services by its institutes and put in place an IPR policy and three-tier intellectual property and technology management mechanism, which fixes resource mobilization targets to institutes, benefits from the government-matching grants scheme for revenues commercially earned by ICAR, and so on. It is following the competitive grants scheme under NAIP as well as the National Fund for Basic, Strategic, and Frontier Application Research in Agriculture (NFBSFARA) of ICAR by selecting the most appropriate supplier for a given research product from the ICAR/SAU system, general universities, the private sector, NGOs, and other scientific organizations and institutions or departments (Mruthyunjaya and Ranjitha 1998). Competitive research or matching grants that especially target and involve the poor are an interesting new approach to increase the participation of the poor in setting the research agenda. Farmers may be given such funding to commission locally mandated research (EIARD 2011). Since AP Cess Fund support is no longer available, creation of a special fund for ad hoc support to research similar to AP Cess Fund scheme is needed because the NFBSFARA is not a substitute for the former AP Cess Fund projects. The management of this fund must coordinate with and complement NFBSFARA to bring in synergy. Block grants, competitive grants, project-based funding, and co-financing by CSIR, Indian Council of Medical Research, Department of Biotechnology, Department of Science and Technology, Department of Ocean Development, and others in interorganizational projects should all be used in a systematic manner. Another approach can be 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. But such efforts should not lead to distortion of core program priorities and action.

Better use of nonplan resources, withdrawal from transfer of technology initiatives (in ICAR), allowing some areas that are more appropriate for private research, reducing bureaucratic overhead, exploiting interinstitutional and interdisciplinary complementarities, and similar means will augment funding resources for NARS. One of the ways ICAR is supporting research projects is through revolving fund support. It has been successful in commercialization of ICAR technologies.

ICAR has been trying over the years to institutionalize computerized online Financial Management System (FMS), particularly during NATP and NAIP, but it has not succeeded as yet. The general financial rules need to be simplified and made user-friendly, and funds should be made available in time to the field-level project and functionaries. Procurement rules need to be simplified for procurement of scientific inputs and services. Some suggestions to strengthen the internal systems of financial management are using manuals and guidelines, mobilizing resources, company floats, venture capital support to scientists with promising technologies, collaborating to upscale technologies that can be commercialized, and others. Projects should not be initiated without adequate funding, both revenue and capital components. Subcritical funding and staffing of projects cannot make an impact.

The last few years have seen significant improvement in buildings, roads, laboratories, classrooms, guest houses, training, and student hostels in ICAR institutions and Deemed Universities, which of course is not true in SAUs. This is good, but what matters is whether adequate budget is available to maintain the infrastructure and support the human resources. After all, the human resources, and not the infrastructure, will shape the future of research and education in the country (India, Planning Commission 2005).

FYP Plan and nonplan expenditure should not be distinct from one another in scientific institutions (India, Planning Commission 2005). The massive nonplan component is rarely scrutinized (Jha and Kumar 2005). Nonplan expenditures initially permit continuation of research efforts through the gestation period, but over time accumulate and swamp the plan resources. The incremental, plan-based approach may serve small systems for some time, but the Indian system has grown so much in size and complexity that substantial support is needed. In collaborative projects with the private sector, the sharing of capital costs should be clear and insisted upon. There is still insufficient understanding of the composition and quality of spending and how these might (or might not) be affected by the decline in funding. Poor data, together with limited knowledge of unit costs, make it hard to accurately assess scale, relevance, efficiency, and effectiveness of public agricultural spending. Both how and how well resources are being used need to be understood before making a judgment on the need for more (ODI 2007).

Academic estimates of returns to research investment are targeted to policymakers and planners. But government funding continues to be accompanied with a load of administrative and financial accountability. The proposition may be that the millions of small and marginal farmers of India, if convinced of the impact, could be a major ally in supporting the professional interest of the agricultural research system. Byerlee and Alex (1998) and Joshi et al. (2005) also suggest that NARIs build political support for public funding of research by increasing public awareness—at all levels—on the role and impacts of research, by developing strong and articulate client organizations that can act as a lobby for agricultural research, and by reforming the effectiveness of NARS to make them more attractive investments.

The critical role of externally aided projects (EAPs), particularly from the World Bank, needs special attention under funding. The EAP share of total national R&D funding is negligible (less than 5 percent), but the role of EAPs in reforming and revitalizing the NARS is significant. It is important to note that the large NARS in India is built mostly from domestic public resources (the private sector contributes nearly 4–5 percent of the total); but external assistance (through EAPs), notably from the World Bank, has played a critical role in R&D capacity development over the years.

Though external assistance was never more than 5 percent of total funding in agricultural research, generally the Indian government followed a selective approach to formulate projects through external assistance, mainly to fill in idea and skill gaps. These projects are considered potential opportunities to experiment with and explore advances in new sciences and application of proven science and technology at a grassroots level with needed institutional and policy changes and organizational and management reforms in the research system to enhance its efficiency to serve science better.

In this context, external assistance to India, notably through World Bank, contributed to support paradigm shifts in agricultural research strategy in relation to changing situations. During the waning periods of the green revolution (1978–1996), research capacity at the grassroots level was perceived as weak, and hence emphasis was given to build strong research infrastructure at the research stations of SAUs through the National Agricultural Research Project (NARP). After strengthening infrastructure at the research-station level in SAUs, severe constraints were placed on the system in the nonavailability of new technologies to suit to the changed context, the near collapse of the public extension system particularly at the district level and below, and the critical need of O&M reforms in the research system as the system grew in size and complexity. Therefore, during 1998–2005, NATP was implemented with emphasis on generation of an adequate number of proven technologies, developing an effective technology dissemination model at the district level and below (the ATMA model), and O&M reforms in the science system. Meanwhile, the context of Indian agriculture again changed. The market has become as important as production. To help ICAR come to grips with the growing importance of the market and agribusiness, to address the problems of the many poor farm families living in disadvantaged areas, and to strengthen its position at the frontiers of agricultural sciences, NAIP was launched during 2006 with the emphasis on increasing productivity, profitability, and competitiveness triggered by advances and innovations in and applications of science in agriculture. In other words, the paradigm envisaged in Indian agriculture shifted from input-based growth to knowledge-, innovation-, and market-based growth.

NAIP is a flagship star project in agricultural research evolution in India. Under it, several firsts and innovations are tested on a moderately higher scale, such as the following examples:

- extensive project campaigning and stakeholder consultation
- preparation and sharing of project implementation plans before launching a project
- financial management manuals
- procurement management manuals and monitoring and evaluation (M&E) manuals prior to project implementation
- a consortium approach
- competitive project funding following a rigorous and highly transparent multilayer review process
- PPP in practice with substantial nonconventional partners
- competent project Principal Investigators (PIs) and co-principal investigators (Co-PIs) and very eminent and wise experts for advise at the project or site level
- creation and effective use of the help desk
- engagement of a professional firm for online M&E job throughout the project
- action research for development (value chain and sustainable rural livelihood security)

- creation and management of a variety of sustainability fund models by farmers for perpetual livelihood security
- variety of market tie-up arrangements under value chain and livelihood security projects
- high-end basic and strategic research to unravel solutions to unresolved persistent problems and to complex emerging, anticipated and unanticipated problems of the future
- co-financing from IFAD and the Sustainable Land and Ecosystem Management Global Environment Fund
- massive HRD initiatives involving large-scale international training and national-level training with national and international experts
- establishment of business planning and development units
- development and use of several e-products like e-theses, e-courses, e-publications, e-journals, and others
- online FMS, agropedia, Agroweb
- digital library and information management
- development and use of environmental and social safeguards framework

The NAIP is specially monitored by India's Planning Commission and Ministry of Finance, besides regular reviews by the World Bank. In view of complex nature and all-India spread of the project, a constant vigil on what is working and what is not and an action plan to make it work must be drawn within the project period or, if that is not possible, during the extended period. Detailed documentation and analysis of successes and failures of projects, ideas, and processes has to be attempted on the above range of process and product innovations and should be shared widely and quickly for use by all concerned parties. The government of India has already initiated the 12th FYP, and the successful models under NAIP must be fed into it for scaling up like the ATMA model under NATP during the 10th FYP. It should be noted that documentation skills are very poor in the Indian NARS and hence need to be immediately upgraded. Further, the attention and importance NAIP gets from the NARS management is no different from any other ongoing project. This is not sufficient because NARS, and particularly ICAR, a science department, has a challenge to take science and innovations alleged to be idling in laboratories to society to enhance social welfare. If this does not happen, the claims on convergence of science with development will remain a myth. Similarly, it will be a missed opportunity if the development departments and other partner agencies involved in NAIP cannot properly jell and collaborate with science and scientists to optimize synergy among resources, institutions, policies, people, and science (projects). Therefore, special attention, seriousness, and follow-up are needed by all involved in NAIP, not only to get a reasonable rate of return on the borrowed credit from the World Bank but also to fulfill its vision, since the entire globe is keenly watching this mega-agricultural innovation project for lessons, replication, scaling up, and scaling out.

4. A Synthesis of Studies and Views from Stakeholders on Agricultural Research for Development Priority Setting, Financing, and Execution

The countries of South Asia, including India, have significantly benefited from investment in agricultural research. The green revolution during 1960s and 1970s consisting of use of high-yielding varieties of crops, fertilizers, and irrigation; and plant protection increased production of major agricultural commodities such as food grains, vegetables, fruits, milk, eggs, and fish several-fold. As a result, the per capita availability of important food items has increased several-fold, despite increase in population. The increase in domestic agricultural production has also made a visible impact on national food and nutritional security. However, poverty and malnutrition still continue to afflict more than one-fifth of the population of the country.

Indian agriculture is dominated with small and marginal farmers. The ratio of agricultural land to agricultural population is about 0.38 ha/person in India, as compared with more than 11 ha/person in developed countries. With a global share of 2.3 percent of the land, 4.2% of water and 17% percent of the population, India has four to seven times less available resources than the world per capita average (NAAS, 2009). The pressure on limited land and water is further intensified with the diversion of agricultural land, water, and labor toward industrial, urban, and nonagricultural sectors. Further, the environmental impact on agriculture is pronounced in several regions and situations. Growth in total factor productivity is stagnating or decelerating. The burgeoning population and rise in income level have led to increase in demand not only for basic food requirements but also for high-value and value-added food products. The increased food production has to be achieved from the limited, diminishing, and degrading resources.

However, all over the globe, including countries in South Asia, the public research resources in agriculture are becoming inadequate in meeting the expanding research objectives and complex agenda for agricultural research, though investment intensity rose from a meagre 0.20 percent during the early 1960s to about 0.50 percent in 2008. This, however, remains way below the average for all developing countries. Since most of the agricultural research and development (R&D) is in the public domain, it is necessary that each research rupee is spent efficiently. Thus there is a need to optimally allocate the available scarce resources, and even more so because of the size of research resources is becoming large (which have alternate uses), aggressive participation in world trade, focus on high-value products, the need for more equitable growth, greater attention to sustainability issues, and other factors are in consideration.

Several formal, objective and subjective approaches for agricultural research prioritization in the Asia Pacific region were attempted in the past, many of which were guided by the Asia Pacific Association of Agricultural Research Institutions (APAARI). Several research prioritization studies were made in India, most using a modified congruence approach providing normative–relative research priorities in terms of regions (states in India) and individual commodities or commodity groups (Jha et al. 1995; Mruthyunjaya et al. 2003; Jha and Kumar 2005). The efforts of APAARI for countries in Asia Pacific are also significant in identifying research priorities using quantitative and consultative approaches initially and a quantitative approach lately (APAARI 1996, 2002; APAARI, ICRISAT and NCAP,2005).

The APAARI efforts in prioritizing agricultural research using the congruence model (for details of methodology, see APAARI 2002) led to identification of seven areas as regional priorities (APAARI 2002). Five of them are related to broad research areas, while the last two are cross-cutting support activities that are important for agricultural research in general. These regional priorities are as follows:

1. Natural resource management
2. Genetic resources
3. Commodity chain development
4. Meeting the protein demand of a growing population
5. Trees and forest management
6. Cross-cutting issue: Information and communication management
7. Cross-cutting issue: Capacity development

The seven regional priority research areas were further broken down into more specific priority research themes within each research area (Appendix 3). The commodity research priorities identified by using modified congruence method are cereals, livestock, cash crops, fruits, vegetables, plantation crops, oilseeds, pulses, fish, roots and tubers, and dry fruits (APAARI 2002.) Jha (2002) reported that the above kind of priority articulation is not very much helpful operationally. Sector goals and objectives provide the starting point for research prioritization, which is an analytical process that requires description of current and projected scenarios for the identified sector goals and objectives; identification of points of stress (constraints) or opportunities for identified commodities, resources, and regions; and the potential contributions of research and other policy instruments. Each constituent unit, region, or zone undertakes this analysis and develops appropriate proposals for funding. These need to be subjected to an analytical prioritization exercise and aggregated to provide a national profile. In addition, maintenance research, agricultural education, library and documentation, communication, and so on, which are critical, should also be a priority.

The South Asia Association of Regional Cooperation (SAARC) comprises the governments of seven countries of South Asia: Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. SAARC developed a Vision 2020 document in 2008 (SAARC 2008), which visualizes how the agricultural scenario could evolve in the near future and what policies and strategies would be appropriate to adjust to the emerging changes and harness their potential. The priorities in agriculture, including agricultural research for different SAARC countries, are defined, followed by stating the way forward. The way forward for the region as a whole, as stated in Vision 2020, include the following:

- accelerating agricultural output growth
- Strengthening the agricultural research, education, and extension system
- supply of adequate, quality seeds and other inputs
- priority to increase production of foodgrains while promoting diversification
- sustainable use of natural resources
- addressing the small-farm structure through creating suitable jobs in the nonagricultural sectors in and around rural areas
- contract farming and cooperative farming

- adaptation to climate change through innovations in technology, institutions, and policies
- suitable policies to address the energy crisis by developing strategies to harness potential of bio-energy crops and tree species and developing technologies for use of agricultural waste and surplus for generating energy
- favorable food price policy
- emphasis on food safety and food standards
- public/private–sector partnerships (PPP)
- intellectual property management
- biosafety and biosecurity
- rural infrastructure
- above all, strong regional collaboration

Jha and Kumar (2005), besides identifying commodity and regional priorities, have also identified resource-orientation priorities for India. Their study revealed that nearly 35 percent of research resources were focused on germplasm, 26 percent on agrochemicals, and 21 percent on soil and water research. More than 55 percent were devoted to raising the productivity of natural resources. Material resources (agrochemicals, power, machinery) altogether claimed about one-third of the resources. The rest was spread over socioeconomic and other resources. Their assessment of the current allocation and the optimum arrived at through research prioritization indicated that all public R&D institutions follow this broad pattern. Private research is generally involved in tradable resources. Hence they concluded that there is no alternative for public R&D for research on public goods. Natural, human, and institutional resources are areas where private research has very selective interest domain, driven entirely by the product-specific interests.

In 2004, APAARI, the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), and the National Center for Agricultural Economics and Policy Research (NCAP) held a workshop, *Research Need Assessment and Agricultural Research Priorities for South and West Asia*. In a report for this workshop, Mruthyunjaya, Pandey, and Jha (2004) have attempted a research needs assessment and prioritization of agricultural research for development (AR4D) in India. They recorded the identified research needs at the microlevel in 28 pilot districts of the National Agricultural Technology Project (NATP), a World Bank–supported research project for India. Using strategic research and extension plans (SREPs), they performed a research gap analysis by agro climatic zones, including research needs versus current research efforts under NATP, and prioritized the research gaps under nine themes:

1. genetic improvement
2. natural resource management (NRM)
3. integrated pest management (IPM)
4. integrated plant nutrient management
5. postharvest technology
6. water management
7. socioeconomics and policy research
8. animal management
9. fish management

Following this prioritization, strategies were suggested to bridge the prioritized research gaps through participatory involvement of research institutions, extension agencies, and development departments.

The research strategy included resynthesis of the technological package per the farming situation and strengthening of on-farm research and on-station research. Similarly, the extension strategy involved improving the productivity and income of the existing enterprises and commodities, diversification and intensification of existing farming systems, improving sustainability in production and income, improving financial sustainability, strengthening farmer organizations, strengthening of marketing infrastructure, and strengthening of private institutions for extension. For each of these strategies, different crops, commodities, and tasks and their corresponding suitable unit size, unit cost, number of units, and total cost were defined. Then the agency implementing the strategy on a pilot scale was defined and directed to implement the task. The research strategy was to impress on research institutions, the Indian Council of Agricultural Research (ICAR) and state agricultural universities (SAUs), that they should address long-term issues using their own funds. In respect of short-term issues like on-farm trials, limited financial support was extended to Krishi Vigyan Kendras (KVKs) by Agricultural Technology Management Agencies (ATMAs). Some limitations of practical use of the strategy and suggestions to overcome them are also highlighted in the report. In fact, this is a good example of microprioritization of AR4D. Table 4.1 shows how shifts in research priorities over time were identified in India.

Table 4.1—Shift in commodity and commodity group research priorities in agriculture and allied sectors in India as reflected in research studies, 1995–2010

Sr. No.	Jha et al. (1995)	APAARI/ NCAP (2002–2003)	Jha & Kumar (2005)	Mruthyunjaya & Kumar (2010)
1.	Cereals • Rice • Wheat • Sorghum • Maize	Cereals	Cereals	Cereals • Rice • Wheat • Local staple cereals Pulses
2.	Livestock • Milk • Goat (meat) • Egg	Livestock	Horticulture	Livestock
3.	Horticulture	Horticulture	Livestock	Horticulture
4.	Oilseeds	Cash crops	Cash crops	Fisheries
5.	Fisheries	Oilseeds	Oilseeds	
6.	Cash crops	Fisheries	Fisheries	

4.1 Key Areas Where Agricultural Research Is Proposed

Research prioritization with respect to commodities and commodity groups for India was attempted by Mruthyunjaya and Kumar (2010) using a modified congruence method (Table 4.1). The study estimated the required investment in R&D in South Asian countries for meeting the projected food demand to attain food and nutritional security for people in 2015 and 2025 under two scenarios: (1) existing growth in food supply (2.14 percent) to meet the national food security, and (2) target growth rate of 4 percent to meet the challenge of hunger and poverty in India. Research prioritization was attempted to meet the projected demand with emphasis on the poor. The emphasis on the poor was accorded since it was observed that priority scores differed with income groups. For example, for all income groups in cereals, the priority score was 31, but for the very poor it was 41 and for the rich it was only 24. Overarching priorities were decided through responses from e-consultation and face-to face-meetings with stakeholders. The priorities are as follows:

- Commodity Priorities
    - Rice
    - Milk

- Commodity/Group Priorities
    - Cereals
    - Horticulture
    - Livestock
    - Fishery
    - Forestry

- Overarching Priorities
    - Natural resource management
    - Socio-economic and policy research
    - Germplasm collection, conservation and improvement
    - Strengthening NARS institutions
    - Strengthen basic and strategic research in the frontiers areas of agricultural sciences

The results of this projection of the research investment requirement for India revealed that at the current annual growth rate of the food supply, the resource funding (at current prices) must be increased to $2,739.3 million from the 2010 level of $1778.0 million by 2020. If a 4 percent growth rate is targeted to meet the challenge of hunger and poverty, it has to be raised to $3,632.9 million from the 2010 level of $2,015.6 million by 2020.

4.2 Agricultural Research Prioritization: The Way Forward

The approaches to agricultural research prioritization are important for their uptake and impact. As stated earlier, the approach has to be both bottom-up and top-down. In this context, the model referred to earlier (Mruthyunjaya et al. 2003) for convergence of macropriorities with micropriorities deserves attention. Research prioritization has to be specific to commodities, groups of commodities, themes, sectors, agroecological zones, and farming systems in which agriculture is actually practiced. Thus agricultural research prioritization is not a one-shot, one-time, one-level exercise. It is a time- and space-intensive, multilevel, and time-and-again exercise. Each level is important as it sets the boundary for optimum research resource allocation at that level. The lower the level of prioritization, the more accurate and appropriate the priorities will be. The prioritization exercise is an information-intensive and human resource–intensive activity. Agricultural economists by virtue of education and experience can lead the activity but cannot complete it without the involvement of other scientists and players in the system. The time frequency of the exercise may be lower at the higher level (say every five years), but it may have to be higher at lower levels of prioritization as changes are frequent and considerable there. The identification of generic priority areas may be adequate to donors to channel funding, but individual organizations of the National Agricultural Research System in the region or any other level may further fine tune them for developing their own focused research agendas (APAARI 2002). It is important that agricultural research prioritization exercises, particularly in developing countries, need to follow some broad principles. These include, among others, an orientation toward smallholders, pastoralists, tribals, fishermen, and agricultural laborers; perspective of farming system research in the ecosystem through need-based diversification; increased participation involving farmers, nongovernmental organizations, women, and youth; value chain; public/private–sector partnership, blending traditional knowledge with modern technologies; community-based resource management; extensive use of information and communication technology; and enabling institution, policy, and governance support.

While identifying research priorities using different methods with a focus on the target clients, the target domain and research approach remain important and should continue, but the explicit use of such priorities in planning and execution of development programs is equally important. In general, it is found that the studies in research priorities are not explicitly referred to while identifying programs. This will dampen the interest of preparation of such exercises and may lead to subjectivity in the preparation of plans and programs, which is not proper. Further, it is important to strengthen research in methodological advances in research prioritization and impact assessment.

5. An Analysis of Potential New Technologies

The cluster or group of new technologies that have a potential of mass use and scalability include hybrid crop technologies, biotechnologies including transgenics and genetically modified organisms GMOs), conservation technologies, nanotechnologies, processing and packaging technologies, biorisk management, mechanical technologies, and information and communication technologies (ICT). As we can see, these new technologies are raising new issues in organizing the National Agricultural Research System (NARS) related to economies of scale, international collaboration, and public–private linkages (Byerlee and Alex 1998). Strengthening national and international alliances with advanced research organizations to access rapid advances in new technologies and knowledge (such as modern tools and products, and upgrading capacity to use and regulate the new technologies especially in intellectual property rights and biosafety) becomes very important to NARS. Since the development of these technologies is expensive, time consuming, and uncertain, encouraging technology transfer between nations to save costs and efforts of duplication and to also allow nations to learn from the successes and failures of others should be given due attention. Three situations can be possible: (1) finding possibilities for nations to adopt the technological advancements of neighboring countries, ipso facto; (2) finding possibilities where lessons from the other countries can be modified per the area- and region-specific needs of the nations; and (3) finding possibilities that are unique to the nations and developing new series of learning and technological innovations for addressing the priority needs of their own countries. Yet another dimension can be that (a) some of these technologies are on the shelf, already commercialized in some areas but need extension and replication in other similar areas; (b) some are not commercialized but require translation research and technology management services to be added; and (c) some are still at the basic and strategic research level. The estimated benefits of some of these new technologies in terms of yield improvement, reduction in production cost, sustainable natural resource use, food production, and exports are provided in ICAR (2009). Appropriate structures and processes are to be planned to handle these dimensions effectively. Regarding new technologies, the following are suggested (www.gov.uk/assets/foresight/docs/food):

- New technologies (such as GMO and the use of cloned livestock and nanotechnology) should not be excluded a priori on ethical or moral grounds, though contrary views to be respected.
- Investment in research on new technologies is essential in light of the magnitude of the challenges for food security in the coming decades.
- The human and environmental safety of any new technology needs to be rigorously established before its deployment, with open and transparent decisionmaking.
- Decisions about the acceptability of new technologies need to be made in the context of competing risks (rather than by simplistic versions of the precautionary principle); the potential costs of not utilizing new technologies must be taken into account.
- New technology may alter the relationship between commercial interest and food producers, and this should be taken into account when designing governance of the food system.
- There are multiple approaches to addressing food security and much can be done today with existing knowledge. Research portfolios need to include all areas of science and technology that can make a valuable impact; any claims that a single or particular new technology are a panacea are foolish.
- Appropriate new technology has the potential to be very valuable for the poorest people in low-income countries. It is important to incorporate possible beneficiaries in decision making at all stages of the development process.

Similarly, needed funding and delivery mechanisms are also to be planned for their uptake. Yet another requirement is strong encouragement to public-private sector research which provides private sector firms with increased opportunities to develop new products (Laxmi et al. 2007).

5.1 Nanotechnologies

Nanotechnology is the manipulation or self-assembly of individual atoms, molecules, or molecular clusters into structures to create materials and devices with new or vastly different properties. The potential of nanotechnology to revolutionize the healthcare, textiles, materials, ICT, and energy sectors is well known. The application of nanotechnology to the agricultural and food industries was first addressed by a U.S. Department of Agriculture Road Map in 2003. The prediction is that nanotechnology will transform the entire food industry, changing the way food is produced, processed, packaged, transported, and consumed (European Nanotechnology Gateway 2006). The main areas where significant investments are made on this technology include the United States, Japan, European Union, China, India, South Korea, Iran, and Thailand. A study by the Helmuth Kaiser Consultancy (Helmuth Kaiser Consultancy, 2004) predicted that the nanofood market will surge from $2.6 billion to $20.4 billion by 2010, which must have increased significantly by now. An estimate by the Business Communications Company, a technical market research and industry analysis company, shows that the market for the nanotechnology was $7.6 billion in 2003 and is expected to be $1 trillion in 2011. However, the full potential of nanotechnology in the agricultural and food industry has still not been realized.

Nanotechnology has the potential to revolutionize the agricultural and food industry with new tools for the molecular treatment of diseases, rapid disease detection, enhancing the ability of plants to absorb nutrients, and so on. Smart sensors and smart delivery systems will help the agricultural industry combat viruses and other crop pathogens. Nanostructured catalysts will increase the efficiency of pesticides and herbicides, allowing lower doses to be used. Controlled environment technology, which is an advanced and intensive form of hydroponically based agriculture, provides an excellent platform for the introduction of nanotechnology to agriculture. Nanotechnological devices for controlled environment technology that provide “scouting” capabilities could tremendously improve the grower’s ability to determine the best time to harvest the crop, the vitality of the crop, and food security issues such as microbial or chemical contamination. Similarly, tiny sensors and monitoring systems enabled by nanotechnology will have a large impact on future precision farming methodologies leading to enhanced productivity in agriculture by providing accurate information to farmers to make better decisions. Nanoscale devices with novel properties could be used to make agricultural systems “smart.” New nanoresearch also aims to make plants use water, pesticides, and fertilizers more efficiently; to reduce pollution; and to make agriculture more environmentally friendly. Particle farming, cleaning soil and ground water, and nanoaquaculture are other potentials. Applications in the food industry include smart packaging, on-demand preservatives, functional or interactive foods, monitoring and tagging of foods, nutrient delivery systems, and methods for optimizing food appearance such as color, flavor, and consistency. However, there is a concern over the use of nanoparticles in food and manipulation using nanotechnologies, which has the potential to elicit the same issues raised in the debate of genetically modified foods. Therefore, more safety data are needed before nanoparticles can be included in food. It (Nanoforum Report 2006, in www. Nanoforum.org calls for an appropriate premarket safety evaluation focusing on the effects of particle size as well as composition. The report concludes, “Finally, it may be possible one day to manufacture food from component atoms and molecules, so called ‘Molecular Food Manufacturing.’ Already some research groups are exploring this.”

Kalpana Sastry et al. (2010) assess the implications of current trends in nanotechnology for the agrifood sector in India using published literature and patent data. They have mapped the research themes in nanotechnology, clearly demonstrated in the multifaceted applications of nanotechnologies in the 12 identified areas across the agricultural value chain for the Indian agrifood systems. They noted that biosynthetic pathways can be identified as a priority area for research investments in agrifood nanotechnology. Regarding safety issues, they suggest involving the stakeholders in the early stage of technology development so that they are aware of the possible risks and uncertainties associated with the use of the new technology. This will alert nanoresearchers and policymakers to risk assessment before commercialization of nanotechnology products.

5.2 Biotechnology

Biotechnology offers improvement in several areas including agriculture, food and nutrition, animal husbandry, fisheries, biosecurity, medicine, and bioenergy. The most compelling case for the intervention of biotechnology is its capability to contribute to (1) increasing crop productivity, and thus to global food, feed, and fiber security; (2) lowering production costs; (3) conserving biodiversity, as a land-saving technology capable of higher productivity; (4) more efficient use of external inputs, for a more sustainable agriculture and environment; (5) increasing stability of production to lessen suffering during famines due to abiotic and biotic stresses; and (6) the improvement of economic and social benefits and the alleviation of poverty. Biotechnological interventions that have already made global impact and offer scope for revolutionizing the agricultural production and farmers’ incomes in the coming years include (1) micropropagation of elite planting material, (2) molecular breeding for accelerated improvement of specific traits by pyramiding of genes available in the species gene pool, (3) molecular diagnostics and vaccines for effective control of livestock diseases, and (4) genetically modified organisms (GMOs) incorporating foreign genes of interest into target crops and animals. Vivid outcomes of biotechnological efforts include Bt-cotton, improved varieties of rice (Pusa Basmati 1 and Sambha Mahsuri tolerant to bacterial leaf blight and Swarna-sub1, Mahsuri-sub1 with ability to tolerate complete submergence in flood water up to two weeks), synthesis of vitamin A in rice endosperm, the golden rice for biofortification of essential nutrients in the foodgrains, conversion of C3 rice plants to C4 plants, creating immunity to rust diseases in wheat and Bacterial leaf blight (BLB) in rice, decoding of pigeonpea genome, Vivek Quality Protein Maize 9, tomato genome sequencing, breeding to develop grape cultivars suitable for winemaking, black pepper cultivars rich in aroma compound, caryophyllene, development of processing tomatoes, potatoes for chip making, white onion with high soluble sugar, papaya varieties for table and papain production, in vitro propagation technologies in banana and potato and citrus, and buffalo cloning. The present and near-future scope of biotechnological research and development in plant, animal, and fish microbial biotechnology is nicely summarized by Singh, R.B. (2012). Pray and Nagarajan (2012) stated that biotechnology innovations went from zero in the 1990s to five genetically modified (GM) traits in hundreds of GM cotton cultivars by 2008; pesticide registrations went from 104 in the period 1980–1989 to 228 during the period 2000–2010; similar growth in innovations also occurred in the agricultural machinery, veterinary medicine, and agricultural processing industries.

Development of transgenic crops expressing a variety of novel traits such as insect resistance, disease resistance, herbicide tolerance, hybrid production, improved oil quality, and others have led to large-scale cultivation of GM crops, which currently occupy 148 million hectares on a global scale. Substantial social, economic, and environmental benefits have been realized worldwide by cultivating GM crops. The spectacular success of GM cotton in India is an instance of the power of GM crops. Prioritized target traits in crop plants, livestock, and fisheries have been identified by the Swaminathan Task Force on Biotechnology (India, Planning Commission 2004).

Currently, about 50 transgenic events in both the private and public sectors in various crops expressing different traits (Anand Kumar, former Director, National Research Center on Plant Biotechnology, New Delhi, India) have been developed after many years of intellectual pursuit by scientists at an average expenditure of INR 6–8 crores on each, ensuring 30 to 40 percent more yield and 20 to 23 percent saving in costs and have been waiting for commercialization since 2006. Our preparedness is grossly inadequate in terms of undertaking translational research for upscaling of technologies and availability of state-of-the-art facilities to quickly undertake prescribed environmental and biosafety tests. Similarly, our capacity is very weak to pursue technology management in terms of scaling out, market research, and commercialization of technologies. Because of this, not only are the scientists demoralized but also society is not benefited by scientific breakthroughs. About half of the scientists belong to public research institutions. The most important crops such as rice, chickpea, mustard, groundnut, tomato, sugarcane, and so on, which express important agronomic traits, are being tested (Appendixes 4 and 5). The benefits of these GM food crops will be blaze new trails and be spectacular in enhancing crop productivity to a great extent, thereby ensuring food and nutritional security to the teeming millions. However, the moratorium imposed on the release of Bt brinjal has affected the morale of the researchers involved in development and testing of these GM crops. The uncertainty currently prevailing is not conducive to the progress of GM technology, the application of which in agriculture is an urgent need in the country. India does not have the luxury of rejecting new technologies for agricultural growth (Pental, 2012).

5.3 Advanced Processing and Packaging Technologies

Research and development of bulk handling systems of fruits and vegetables, livestock, fishery products including precooling and storage and postharvest protocols for sea transport, safe disinfection such as vapor heat treatment for export of fresh products, extension of shelf life by preventing desiccation, nutrient-specific probiotic food processing, residue-free integrated pest management (IPM) technology, and cool chambers on the principles of evaporative cooling are some of the technological advances being pursued (NAAS 2009). Value addition through dehydration of fruits and vegetables, including freeze-drying, dried and processed fruits and vegetables, spices, and fermented products are being developed. The opportunities in the fast-food business include development of new products like juices, chips, essential oils, fruit wines, extruded products from millets, extractors for chilies, tomato, tamarind seeds, pomegranate arils, dried powders from beetroot, carrot, green chilies, sarson saag, ginger, garlic, onion, and so on. Packing materials like corrugated fiberboard boxes, perforated punnets, cling film wraps, and sachets are being standardized for packaging of different fresh horticultural produce (India, Department of Agriculture and Cooperation 2012).

5.4 Resource Conservation Technologies

Organic agriculture integrated with resource-conserving technologies has great potential in minimizing degradation of land–water resources while keeping the environment relatively clean. The conservation-agriculture-based agrotechnological package not only saves a substantial quantity of water at no extra cost but also helps in producing more at low costs, improves soil health, promotes timely planting, ensures crop diversification, and reduces environmental pollution and adverse effects of climate change. Such technologies include laser land leveling, double till, no-till in the rice–wheat system, avoiding soil compaction with a turbo seeder, dual-purpose wheat technology for fodder and grain production, diversification and adoption of microirrigation technology in irrigated areas, watershed management in arid areas, and so on (HKA 2012).

5.5 Information and Communication Technology and Remote Sensing

Rapid growth of computer science led a number of ICT applications to use an integrated model-based system with database system concepts, including decision support systems, executive support systems, management support systems, and process-oriented information systems. These systems need to be further used in different sectors like water management, soil management, plant protection, market prices, weather advisory, and so on. Similarly, their use is being pursued in space technology particularly, and in the application of satellite remote sensing; finding new resources; optimally managing the presently available resources, crop acreage, and yield estimation; crop condition assessment; crop yield modeling; flood monitoring and mapping; surface water management; water quality mapping; drought monitoring; and land resource management. These uses are immense but their applications in the future include precision agriculture, monitoring of climate change, risk management and enterprise insurance, spatial data modeling and mining, small area estimation, and so on (NAAS 2011).

One area in which ICT tools can be highly useful is agricultural extension. This vital service, being government run, is currently in shambles across all states and is actually proving to be the weakest link in the transfer of modern technology and its deployment in farmers' fields. The reach of these state government extension agencies is rather limited; extension workers generally do not manage to contact even half of the total farmers. The rest are completely left out. ICT can, obviously, increase the reach of these extension services and speed up the message delivery system. The real ICT-enabled information boom in the farm sector is yet to come (Sud, 2012). Tailored, multidisciplinary, and social media–based approaches to extension that support communities of practice have greater benefits. One example that deserves attention is young farmers in the United States who are using YouTube videos for farm advisory.

5.6 Biorisk Management

The integrated pest management (IPM) strategy with location-specific adaptation needs to be focused; resources are inadequate. More regional-level institutions taking the whole farming system as the clientele need to be put in place in different parts of the country, innovating location-specific technologies including chemical, biological, and cultural ingredients to minimize pest and disease losses to commodities (NAAS 2011). IPM practices have reduced overdependence on pesticides that effectively suppress various pests. The recent alignment of such IPM modules into BIS (Bureau of Indian Standards) standardized GAPs has brought credible alignment with World Trade Organization (WTO)-supported trading of agricultural commodities (India, Department of Agriculture and Cooperation 2012). Intensification of breeding for stem rust strain Ug99 is in progress. With development of new biotic stress problems such as three mealy bug species in various crops, *Spodoptera* damage in soybean and cotton, mites, thrips, and root knot nematode in rice, research programs are put in place to address such emerging problems so as to provide adequate mitigation to farmers (India, Department of Agriculture and Cooperation 2012). Transboundary movement of pests (insects, mites, diseases, nematodes, and weed seeds) and animal diseases need careful planning and execution through meticulous implementation of laws and rules by all states and through support by the federal system. A huge capacity development in human resources and infrastructure is required to pursue further research and monitor this area (India, Department of Agriculture and Cooperation 2012).

5.7 Mechanical Technologies

Mechanization of agricultural operations is important for increasing efficiency of farm operations and overcoming the serious labor shortage in some seasons. Private manufacturers will play an important role in commercialization of modern farm implements, which can be easily adopted by resource-rich farmers. Public-sector research should lead strategic research in supporting the manufacturing industry, keeping in view the interest of small and marginal farmers. Also, some specific needs should be met, like mechanization for small farmers either through development of appropriate farm machines or facilitation of a custom-hiring system in rural areas. Gender-friendly devices also need to be worked out (Singh, R.B. 2012). Some significant technology developments in farm mechanization in recent years include a precision seeder, manure spreader, root crop harvester, garlic planter, vegetable seedling planter, hydraulic platform for fruit harvesting, straw combine with integrated trailer, tractor mounted forage harvester, and others.

As stated earlier, private-sector innovation is expanding rapidly in India, and its role in investing and using advances in new technologies will be increasing in future. According to Pray and Nagarajan (2012), the major reasons for the rapid growth of private-sector participation in agricultural research in India are increase in market demand for agricultural products and agri-inputs, policy liberalization by the government, advances in basic sciences and engineering, strengthening of intellectual property rights (IPRs), and government investment in AR4D. The authors suggest some policy options to encourage further participation of the private sector, like continued stable policy liberalization in the agribusiness sector, more investment in AR4D, strengthening IPRs further to provide greater incentives for research and innovation, and encouraging the growth of rural business hubs and supply chains established by the agroprocessing industry that supply technology and market opportunities to poor farmers and job opportunities to agricultural laborers.

6. A Strategic Plan for Enhancing Agricultural Research for Development

It is firmly believed that the underlying structure, organizational culture, managerial and financial norms and procedures, innovative and bold policy initiatives, political economy factors, program planning, and monitoring and evaluation practices decide the policies, investments, pace, and pattern of performance of every sector of the economy, including agricultural research for development (AR4D). The strategic plan has to factor in this reality, while extending the gains of available technologies, from biotechnologies and other new technologies, and from investing in basic and strategic research, both internal and imported. Further, the strategy has to move from knowledge generation to innovations and use by involving all stakeholders at all levels. The strategic plan in terms of new knowledge, capacities, and skills includes proposals on research priorities and structural, process, and funding changes. It is important to recognize that the new knowledge, capacities, skills, research priorities, structures, processes, and funding mechanisms can contribute to improved livelihood of the poor only when complemented with adequate and effective investment in providing agroservices and with able governance and commitment, primarily from the government, the dominant player in providing research services. But involvement of private sector in a public/private–sector partnership (PPP) mode in each investment activity will be necessary, as can be seen from some success stories in the country (Pray and Nagarajan 2012). The lessons learned in such PPP success stories suggest that the dialogue on PPP roles in agricultural research and development (R&D) has to move beyond partnership as clear domains of comparative advantage (for example, seed, agrochemicals, and farm equipment and machinery) are emerging and public systems need to respond to them (Jha and Kumar 2005; Pray and Nagarajan 2012). The role of the private sector becomes more and more important while balancing diverse and competing research agendas and with development and application of new technologies.

6.1 Priority Proposals

The research priorities identified for India by Mruthyunjaya and Kumar during the Global Conference on Agricultural Research for Development were reviewed during the preparation of this report, particularly the country dialogue meeting at New Delhi on July 2, 2012. The policy dialogue meeting was attended by 32 resource people carefully identified to represent different stakeholder interests, including resource people from Bangladesh and Nepal. After the country needs-assessment report presentation, the participants were divided into four groups covering (1) research priorities, (2) structural and institutional priorities, (3) funding priorities, and (4) technology dissemination and delivery priorities. The groups were briefed to discuss and identify 10 important recommendations under each topic. The group recommendations were examined by all the participants through a gallery walk and subjected to director general voting, and the recommendations were ranked and shared in the meeting. While proposing revised priorities, the groups emphasized following the principles of a farming system approach with small farmer orientation, use of an agricultural innovation system approach, inclusion of legumes in cropping systems, using dual-purpose (food and fodder) crops, diversifying the production system, blending traditional wisdom with modern technologies, and encouraging PPP wherever needed and mutually beneficial. The consensus recommendations for

India with respect to each of the four topics stated above through these processes are provided in Table 6.1 and described in the following sections.

Table 6.1—Priorities for agricultural research for development in India

(1) Research Priorities	(2) Structural Change Priorities	(3) Funding Priorities	(4) Technology Delivery Priorities
Commodity Priorities Rice, maize, wheat, milk, pulses, oilseeds **Commodity Group Priorities** Cereals, horticulture, livestock including poultry, fishery, high-value agriculture **Resource Management and Other Priorities** Natural resource management including adaptation to climate change, resource conservation, water use efficiency, value chain and market integration, GRM (Genetic Resource Management), biotechnology farm mechanization, processing, value addition, rural energy use and management, transboundary diseases	1. Political will to adequately fund AR4D and support NARS must be developed 2. ICAR to be mainly a policymaking organization, brain trust, think tank 3. Addressing of women & youth issues and involvement in research 4. Consortium mode of conducting research to be strengthened 5. Greater autonomy in the NARS 6. Balanced investment in research, education, and extension; strengthen basic and strategic, socioeconomic, and policy research; research on harsh ecosystems; research on rural non-farm (RNF) enterprises; strengthen PPP 7. Focus research, build centers of excellence, more IARI type of institutes 8. University system direct deals with farmers to bridge the knowledge gap 9. Redefine the ultimate beneficiary of research to include farmers, farmer organizations, government and nongovernment organizations, processors, traders, private sector, and so on 10. Effective science communication and policy dialogue	1. Timely funding 2. Transparency in funding 3. Enhance funding 4. Funding for technology dissemination 5. Funding for HRD 6. Long-term planning of AR4D 7. Funding criteria to be broad based and balanced to cover all aspects of AR4D 8. Funding for advocacy of research results 9. Involve stakeholders in funding decisions 10. Equity in funding to all potential research providers	1. Technology breakthroughs for yield improvement 2. Promote technology commercialization 3. Recognize innovative farmers and promote innovations 4. Technology extension through partnerships 5. Stable policy for adopting technology by dispelling myths about the benefits of new technologies and other policy and institutional innovations 6. Open-door policy for import of foreign technology 7. Promote producer companies 8. Promote role players in upstream research and downstream work in extension 9. Dovetail recommendations of research and extension agencies in technology dissemination 10. Promote innovations in developing high-yielding and pest-resistant seeds

Source:
Notes: HRD, human resource development; IARI, Indian Agriculture Research Institute; ICAR, Indian Council of Agricultural Research; NARS, National Agricultural Research System; PPP, public/private–sector partnership.

6.2 Research Priorities

The research priorities were divided among the following categories:

- Commodity Priorities
    - Rice
    - Milk
    - Pulses

- Commodity Group Priorities
    - Cereals (rice, wheat, local staple cereals)
    - Horticulture (integrated pest management, or IPM; integrated nutrient management, or INM; off-season vegetables and flowers; periurban cultivation; arid horticulture; protected cultivation; supply chain management)
    - Livestock including poultry (selective breeding, animal health, processing and market development, crop–livestock system, feed, fodder crop residue management)
    - Fishery (postharvest management, biosafety, environmental impact, sustainable shrimp farming, crab and ornamental fish, genetic enhancement and disease resistance in inland fishery, fish health management, deepwater rice-fish culture, freshwater prawn, integrated fish farming, open-water fish culture, coldwater fish culture)

- Resource Management Priorities
    - Natural resource management, or NRM (soil-water-nutrient use efficiency, reclamation of problem soils, climate-smart agriculture, conservation agriculture, biodiversity, IPM/INM)
    - Germplasm collection, conservation and genetic improvement (biotechnology, hybrids, transgenic, improved seed systems)

6.3 Structural and Institutional Change Priorities

6.3.1 Structural Change Priorities

NARS has to function as science organization, not as a government secretariat as now, by framing science-friendly structures, flexible rules, and procedures with built-in accountability and with decentralization of power down the line. This requires perfect clarity by the workforce in the organization as to whether they are primarily officers or scientists. Similarly, the officers in the Department of Agricultural Research and Education (DARE) and administration and finance in the Indian Council of Agricultural Research (ICAR) need to realize that their main role is to serve science rather than bureaucracy. It is surprising that despite provisions in the rules and bylaws of the ICAR Society to frame its own rules and procedures using mutatis mutandis facility, ICAR still follows the rules of the Indian government ipso facto. The stand by ICAR that rules and bylaws of ICAR Society are adequate in contrast to repeated suggestions for amending them by several review committees is an important issue that needs to be settled once for all time.

ICAR has grown so much in size, spread, and diversity that efficiently managing it has become very difficult, if not impossible. There is a real need to rationalize, integrate, consolidate, and amalgamate its institutes, as repeatedly recommended by several ICAR review committees.

NARS needs to be structurally organized to address problem-solving, multidisciplinary, location-specific research covering harsh ecologies using a farming-system approach oriented toward small farmers and women. The present trend of forming disciplinary-based state agricultural universities (SAUs) negates this principle. The present setup of ICAR with a focus on subject matter divisions is outdated and cannot practically promote problem-solving research, as observed by several review committees. Further, though all types of research are important and should be pursued, the focus of research to be selected by a research agency will depend on the competitive advantage of the agency.

For example, ICAR has the competitive advantage in basic, strategic and to some extent anticipatory research, whereas SAUs have the competitive advantage in adaptive and applied research.

Translational research for scaling out patents, innovations, technology management services including technology incubation, and entrepreneurship development should be adequately strengthened in NARS to minimize the huge time lag between technology breakthroughs and technology adoption by end users. Several high-potential technological breakthroughs wait to pass through the regulatory system for many years. Agri-Innovate India, a new company established under ICAR, needs to take a proactive interest in translational research, technology management, and technology commercialization. The active involvement of the private sector will be very much needed here.

In the NARS, particularly ICAR, adequate decentralization of power and authority to the field units is required to minimize the growing problem of management with the increase in size of the organization. But decentralized power has to be made mandatory after ensuring human resource development (HRD), building trust, and framing flexible rules and procedures with needed accountability.

The agricultural education system that followed the land-grant model for more than 50 years requires reorientation now. The proposed National Agricultural Higher Education Project is a good opportunity for review and revitalization of the agricultural education system in India.

ICAR needs to strengthen SAUs much more than is currently being done as adjunct institutions and real partners to share its agenda. This is a win–win situation to both, as ICAR has limited manpower and an expanding work load and SAUs have limited funds and available human resources. ICAR has to focus more on serving as a think tank, planning, funding, visioning, monitoring and evaluation (M&E), and policymaking organization than engaging in micromanagement of its constituent institutions. States have to seriously think about sanctioning more manpower before opening new SAUs.

The three pillars of strength following the land-grant model of agricultural research are integration of research, education, and extension. All three functions are important to harness the best from science for societal welfare. It is felt that extension and education are getting a better deal in resource allocation than research. This needs critical review and suitable action. Similarly, resource allocation to emerging areas of livestock, fishery, and postharvest management needs review and response.

Research grants need to involve all stakeholders in defining the research agenda, monitoring, and impact assessment. This will help to build ownership, involvement, and appreciation by the stakeholders and the much-needed public support of AR4D. Strengthening socioeconomic, policy analysis, and agricultural research management skills is crucial to enable the research system to function efficiently. Another step that can reinforce policymakers and public support is the effective communication of research achievements and constraints by scientists to policymakers and the public. Generally, scientists in the NARS need to substantially strengthen their communications skills.

6.3.2 Institutional (Process) Change Priorities

Many scientists dislike dealing with financial and procurement management relating to research projects as these functions are outside their expert domain and are sources of inconvenience and harassment. But scientists can easily pick up some proficiency in them if awareness is created to convince them that these skills are needed and important and if these tasks are made simple, less time consuming, and friendly to promote scientific work and excellence.

Another best practice generally disliked and resisted by scientists is objective, analytical research prioritization and monitoring and evaluation (PME) as an aid to better decisionmaking. Scientists argue that they have experience and wisdom about research priorities and that they monitor and evaluate results. They fail to appreciate and comprehend the complexities, budget outlay involved, and consequences of wrong decisions if taken on subjective basis. But it is now universally felt that making PME mandatory is essential to optimizing use of resources so that bureaucracy will not point fingers toward the research system. Again, extensive awareness building, making PME simple and less cumbersome, and improving the PME skills of the AR4D workforce is very important. Building this skill and promoting this practice is an acutely need in SAUs.

Investment in organizational and management reforms to overcome financial and operational problems has been found to be as important as investment in research. Therefore, NARS has to bring in reforms to do business differently and become locally relevant and globally competitive. HRD is always considered a critical input to management of change and attaining excellence in work. But generally HRD gets the least importance, and sometimes even the budgeted HRD outlay remains unused. HRD should be meticulously planned and heavily and liberally invested in, as done by China in the agricultural sector, Brazil, Vietnam, Malaysia, and other countries. This requires framing and implementing a visionary HRD policy.

A general opinion exists that NARS has a leadership crisis, which is attributed to the procedure of finding and selecting able and inspiring leaders. NARS has to change the selection process of senior research leaders like deputy director generals and vice-chancellors, as done in Consultative Group Centers. Clear-cut practices should be developed for succession planning toward leadership change in the system and for a progressive training policy to upgrade the skills of the workforce.

Regular recruitment based on systematic recruitment planning is necessary to maintain the required balance among different cadres in the system. Cadre imbalances will contribute to inefficiency and lower morale of scientists in the system. Framing and implementing a progressive human resources policy covering manpower planning, recruitment, promotions, transfer, training, pensions, and so on is critical.

NARS has to invest heavily to improve soft skills of scientists—communication, publicity, PME, visioning and technology foresight, and policy dialogue. For want of such skills, scientists are not able to establish truths and debunk several existing myths (*Economic Times* 2012), and this is a barrier for attaining prosperity through advances in science.

The success of NARS depends on its ability to balance competing agendas in research, education, extension, funding, and governance. The conditions of success include willingness at the top level, higher capacity and commitment of the scientific community, better governance of scientific organizations, improved scientific infrastructure, national and international partnerships, better funding mechanisms, and enabling institutions and policies.

6.4 *Funding Priorities*

NARS has to increase research funding by three to four times. Agricultural research is multidisciplinary, site- and location-specific, and needs scientific advances in response to more complex challenges including climate change. Modern science is capital intensive, and technology dissemination requires more funding than research itself. All these suggest greater investment in AR4D. As a rule of thumb, invest at least 1 percent of agricultural gross domestic product (GDP) in AR4D in the short run and 2–3 percent of agricultural GDP in the medium and long run.

Agricultural operations are season bound and need to perform the operations on time, so timely release of funds become critical. Untimely release affects operations, output, and fund utilization. Equally important are transparency and equity in allocations and utilization involving stakeholders as far as possible, and flexible rules to utilize funds; otherwise, delayed use or no use of funds will take place. Flexibility may be permitted, however, with clear-cut accountability norms so that proper use of public funds is ensured.

Innovative funding mechanisms can expand the sources and creative use of funds. Examples are block grants, matching grants, cofinancing, project-based budgeting, competitive grants, revolving funds, farmer-supported research funds, funding to farmers to take up location-specific research, and technology commercialization to mobilize research funds with clear intellectual property rights rules.

Technology is no long a free good, particularly after the entry of the private sector, where heavy investments are made in agricultural research to harness the potential of modern technologies. Better policies of PPP, trust and transparency, information sharing, more investment R&D and HRD, more favorable financial and tax incentives from the government will attract higher private-sector participation in research.

No distinction should be made between FYP Plan and non-plan expenditure in scientific institutions. Over time, nonplan expenditure accumulates and swamps plan resources, which is very critical to big research organizations like ICAR.

Serious implementation of externally aided projects (EAPs) and extensive use of lessons learned from EAPs to revitalize the research system is very important. The EAPs are opportunities for piloting innovative scientific and business practices like PME, MIS/FMS, HRD, and so on, as the EAPs are launched through borrowed funds in the research system. If they are not fully implemented and mainstreamed into the regular system afterward, the system remains archaic and inefficient.

A strong lobby should be built for public funding of agricultural research by evaluating and demonstrating the systemwide impact and worth of research to society and conveying it to policymakers and the general public through very effective communication. It would need special funding for advocacy of research results.

6.5 *Technology Delivery Priorities*

Krishi Vigyan Kendras (KVKs) in the NARS and Agricultural Technology Management Agencies (ATMAs) in the public extension system have become the only available and dependable functional extension agencies at the district level and below. However, not much coordination and convergence of their activities is seen at the present. Similarly, there is not much synergy in their activities with a plethora of programs of other development departments. Strengthening both in terms of more funding and manpower in all the existing and emerging areas of importance, and ensuring functional convergence of KVKs with ATMAs and other development departments with clear-cut work and resources, are necessary to strengthen technology dissemination at the district and lower levels.

Use of ICAR's suggested framework for technology development (with emphasis on yield and quality improvement, stress resistance, blending with traditional wisdom, and so on) and dissemination and commercialization (Figure 3.2) is needed. The framework logically optimizes synergy in terms of a range of activities (basic and strategic research to applied and adaptive research to technology assessment, refinement (TAR) and development programs), range of institutions (ICAR; SAUs; private sector; KVKs; ATMAs; zonal research stations; village panchayats (VPs); farmers, farmer organizations, and producer companies from national and regional to district, taluk/block, and village levels), and range of innovations and outputs at each institution and geographic or planning level.

ICAR cannot and should not take up public extension responsibilities. ICAR is a technical organization to provide proven and profitable technological backup to agricultural development in India. ICAR's engagement in public extension activities will be a nonoptimal use of time and intellectual resources and therefore not appropriate. However, ICAR should be in continuous contact with development departments to refine and upgrade the technologies, innovations, processes, and products from time to time with focus on small farmers, women and youth, diversification in farming system perspective, harsh ecologies, PPP, food and nutritional security, and so on.

Extensive use of modern information and communication technologies (ICTs) like mobile telephones is important to address the information and awareness needs of millions of farmers and other end users of agricultural technologies and agroadvisory services. ICTs are the only effective and cheaper means to reach the vast unreached end-user communities. Investment in building awareness, content, connectivity, and infrastructure is critical for success in this endeavor, including attaining the aim of the National Agricultural Policy to move toward a regime of financial sustainability (realistic cost recovery) of extension services.

Strong research to suggest new methods and methodologies in public extension is needed. Innovative extension methods and methodologies are to be developed to cope with the challenge to reach the vast and highly diverse unreached masses. Public research on this has slowed down in recent years, creating a big vacuum. The private sector is relatively better off in this area.

7. Summing Up

The Indian National Agricultural Research System (NARS), led by the Indian Council on Agricultural Research (ICAR), is a big and highly evolved agricultural research system in South Asia. It is still struggling with bureaucratic rigidities with less functional autonomy and insufficient decentralization of powers down the line. It is also overgrown in size, spread, and institutional diversity, which needs review, rationalization, integration, and consolidation. It has taken up too many initiatives that it cannot manage—initiatives that need prioritization, focus, and serious implementation to make systemwide impact. This report attempted to provide a strategy in terms of priorities in research, structure, process, funding, and technology delivery. But it is important to identify the top 10 priorities, irrespective of type, for future agricultural research for development (AR4D). These are as follows:

1. Ensure functional autonomy to ICAR and its institutes through reducing bureaucracy and by framing rules and procedures with sufficient powers decentralized down the line (refer to Sections 3.1 and 6.2).
2. Introspect, review, and avoid institutional and program proliferation in ICAR through integration, amalgamation, rationalization, consolidation, and even possibly downsizing if necessary. ICAR should function as a lean, thin, think-tank, brain-trust organization with a focus on policymaking, visioning, and national–regional–global collaboration, coordination, and convergence (refer to Sections 3.1 and 6.2).
3. Intensify multidisciplinary research with a farming system perspective oriented toward small farmers and women and focusing on harsh ecologies; use a consortium mode involving the private sector and all other research partners on commodities (rice, wheat, maize, pulses, and milk), commodity groups (cereals and staple cereals, horticulture, livestock including fishery, and small livestock), resource management (natural resource management including adaptation to climate change and genetics resource management), and transboundary diseases (refer to Section 6.1).
4. Strengthen translational research and technology management capacity for patenting and scaling out innovations with adequate state-of-the-art facilities and skilled manpower to quickly convert technology breakthroughs to benefit farmers and the industry (refer to Sections 5.2 and 6.3).
5. Strengthen and reorient the agricultural education system, based on the review of more than 50 years of experience of the land-grant model of education and on the emerging and future needs and second-generation problems of agricultural education. This can be done through liberal funding strict quality control, and policy support to establish state-of-the-art facilities and upgrade all agricultural universities and state agricultural universities as centers of excellence (refer to Sections 3.1, 3.2, and 6.3).
6. Strengthen and forge the functional relationship for higher convergence of the frontline extension system (Krishi Vigyan Kendras) with all development programs relating to agriculture and allied sectors, including Agricultural Technology Management Agencies. This includes adequate manpower trained in subjects of agriculture and allied sectors, including modern information and communication technologies (ICTs), and the necessary mobility and electronic connectivity to reach inaccessible areas and farmers to provide knowledge input with and adequate and effective input and service delivery system (refer to Sections 3.1 and 6.6).

7. Increase investment in AR4D from the present 0.5 percent agricultural gross domestic product to at least 1 percent in the 12th FYP, 1.5 percent in the 13th FYP, and 2–3 percent subsequently. Maintain the needed balance between agriculture and allied sectors while allocating resources (refer to Sections 3.3 and 6.5).
8. Strengthen human resource development nationally and internationally by liberal funding and a progressive training policy focusing on planning, deputation, and proper utilization of trained human resources (refer to Sections 3.2 and 6.4).
9. Strengthen research on secondary agriculture in and around rural areas covering rural storage, primary processing, value addition, low-cost packaging, grading and standardization, basic awareness about quality testing and safety standards, rural energy (biogas, wind energy, solar energy) management, small-farm mechanization, precision farming, polyhouse production, and all other agricultural engineering aspects involving self-help groups, producer companies, cooperatives, and other local initiatives (refer to Sections 5.3, 5.6, and 6.1).
10. Strengthen soft skills of agricultural researchers in research policy, long-term planning, visioning, socioeconomics, agribusiness management and policy, advanced computing, use of ICTs, PME, intellectual property rights, participatory research, research documentation, communication, policy dialogue, and publicity to improve implementation of programs, systemwide impact, and increased visibility and credibility of NARS (refer to Sections 3.2, 3.3, 6.4, 6.5, and 6.6).

The top two priorities relate to overcoming institutional deficiencies of less autonomy, insufficient decentralization, large size, wide spread, and overdiversification in institutions. The third priority relates to intensification of research on commodities, commodity groups, and resource management following some basic principles. The fourth priority relates to strengthening translational research and technology management to convert technological breakthroughs to the benefit of farmers and industry. The next two, agricultural education and technology delivery, are the other two pillars of AR4D that have become weak over the years and hence require reorientation and strengthening. The next priority is to increase funding on research, which is inadequate presently, to meet the expanding, complex, and diverse agenda. The next priority is promoting secondary agriculture in and around villages to involve farmers, farmer groups, and producer companies in primary processing, grading, quality and safety awareness, rural energy use, small farmer mechanization, precision farming, and so on, with a primary goal of integrating farming and the market, and an ultimate goal of rural entrepreneurship development, creation of rural nonfarm jobs, and more income to link farmers with the market and the industry. The final priority is to equip the research system with soft skills to improve the efficiency and visibility of the research system.

Appendix 1: List of ICAR/DARE Institutions

Deemed Universities	
1	Indian Agricultural Research Institute, New Delhi
2	National Dairy Research Institute, Karnal
3	Indian Veterinary Research Institute, Izatnagar
4	Central Institute on Fisheries Education, Mumbai
Institutions	
1	Central Rice Research Institute, Cuttack
2	Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora
3	Indian Institute of Pulses Research, Kanpur
4	Central Tobacco Research Institute, Rajahmundry
5	Indian Institute of Sugarcane Research, Lucknow
6	Sugarcane Breeding Institute, Coimbatore
7	Central Institute of Cotton Research, Nagpur
8	Central Research Institute for Jute and Allied Fibers, Barrackpore
9	Indian Grassland and Fodder Research Institute, Jhansi
10	Indian Institute of Horticultural Research, Bangalore
11	Central Institute of Subtropical Horticulture, Lucknow
12	Central Institute of Temperate Horticulture, Srinagar
13	Central Institute of Arid Horticulture, Bikaner
14	Indian Institute of Vegetable Research, Varanasi
15	Central Potato Research Institute, Shimla
16	Central Tuber Crops Research Institute, Trivandrum
17	Central Plantation Crops Research Institute, Kasargod
18	Central Agricultural Research Institute, Port Blair
19	Indian Institute of Spices Research, Calicut
20	Central Soil and Water Conservation Research and Training Institute, Dehradun
21	Indian Institute of Soil Sciences, Bhopal
22	Central Soil Salinity Research Institute, Karnal
23	ICAR Research Complex for Eastern Region including Center of Makhana, Patna
24	Central Research Institute of Dryland Agriculture, Hyderabad
25	Central Arid Zone Research Institute, Jodhpur
26	ICAR Research Complex, Goa
27	ICAR Research Complex for North Eastern Himalayan Region, Barapani
28	National Institute of Abiotic Stress Management, Malegaon, Maharashtra
29	Central Institute of Agricultural Engineering, Bhopal
30	Central Institute on Postharvest Engineering and Technology, Ludhiana
31	Indian Institute of Natural Resins and Gums, Ranchi
32	Central Institute of Research on Cotton Technology, Mumbai
33	National Institute of Research on Jute and Allied Fiber Technology, Kolkata
34	Indian Agricultural Statistical Research Institute, New Delhi
35	Central Sheep and Wool Research Institute, Avikanagar, Rajasthan

36	Central Institute for Research on Goats, Makhdoom
37	Central Institute for Research on Buffaloes, Hisar
38	National Institute of Animal Nutrition and Physiology, Bangalore
39	Central Avian Research Institute, Izatnagar
40	Central Marine Fisheries Research Institute, Kochi
41	Central Institute Brackishwater Aquaculture, Chennai
42	Central Inland Fisheries Research Institute, Barrackpore
43	Central Institute of Fisheries Technology, Cochin
44	Central Institute of Freshwater Aquaculture, Bhubneshwar
45	National Academy of Agricultural Research and Management, Hyderabad
National Research Centers	
1	National Research Center on Plant Biotechnology, New Delhi
2	National Center for Integrated Pest Management, New Delhi
3	National Research Center for Litchi, Muzaffarpur
4	National Research Center for Citrus, Nagpur
5	National Research Center for Grapes, Pune
6	National Research Center for Banana, Trichi
7	National Research Center on Seed Spices, Ajmer
8	National Research Center for Pomegranate, Solapur
9	National Research Center on Orchids, Pakyong, Sikkim
10	National Research Center Agroforestry, Jhansi
11	National Research Center on Camel, Bikaner
12	National Research Center on Equines, Hisar
13	National Research Center on Meat, Hyderabad
14	National Research Center on Pig, Guwahati
15	National Research Center on Yak, West Kemang
16	National Research Center on Mithun, Medziphema, Nagaland
17	National Center for Agricultural Economics and Policy Research, New Delhi
National Bureaus	
1	National Bureau of Plant Genetics Resources, New Delhi
2	National Bureau of Agriculturally Important Microorganisms, Mau, Uttar Pradesh
3	National Bureau of Agriculturally Important Insects, Bangalore
4	National Bureau of Soil Survey and Land Use Planning, Nagpur
5	National Bureau of Animal Genetic Resources, Karnal
6	National Bureau of Fish Genetic Resources, Lucknow

In the 11th Five-Year Plan, total of 185 institutions: 45 institutes, 6 national bureaus, 4 deemed universities, 17 national research centers, 25 Project Directorates, 61 All India Coordinated Research Projects, 17 networks, and 10 other programs.

Appendix 2: List of Agricultural Universities

Andhra Pradesh	3	Acharya NG Ranga Agricultural University, Hyderabad
		Sri Venkateswara Veterinary University, Tirupati
		Horticulture University, Venkataramanagudem near Tadepalligudem, West Godawari
Assam	1	Assam Agricultural University, Jorhat
Bihar	2	Rajendra Agricultural University, Pusa, Samastipur
		Bihar Agricultural University, Sabour, Samastipur
Chhattisgarh	1	Indira Gandhi Krishi Vishwavidyalaya, Raipur
New Delhi (Deemed to be)	1	*Indian Agricultural Research Institute, Pusa-110012, New Delhi*
Gujarat	4	Junagarh Agricultural University, Junagarh
		Sardarkrushinagar-Dantiwada Agricultural University, Sardar Krushinagar, Banaskantha
		Anand Agricultural University, Anand
		Navsari Agricultural University, Navsari
Haryana	3	Ch. Charan Singh Haryana Agricultural University, Hisar
		Lala Lajpat rai Univ. of Veterinary and Animal Sciences, Hisar
Deemed to be		*National Dairy Research Institute, Karnal-132001, Haryana*
Himachal Pradesh	2	Dr. Yashwant Singh Parmar University of Horticulture & Forestry, Solan, Nauni
		Ch. Sarwan Kumar Krishi Viswa Vidalaya, Palampur
Jammu & Kashmir	2	Sher-E-Kashmir University of Agricultural Sciences & Technology, Jammu
		Sher-E-Kashmir University of Agricultural Sciences & Technology of Kashmir, Srinagar
Jharkhand	1	Birsa Agricultural University, Kanke, Ranchi
Karnataka	4	University of Agricultural Sciences, Dharwad
		University of Agricultural Sciences, Bangalore
		University of Agricultural Sciences, Raichur, Karnataka
		University of Horticultural Sciences, Navanagar, Bagalkot, Karnataka
Kerala	3	Kerala Agricultural University, Vellanikara, Trichur
		Kerala University of Animal Sciences, Directorate of Dairy Development, Pattom, Thiruvantapuram
		Kerala University of Fisheries & Ocean Studies, Papangad, Kotchi, Kerala
Madhya Pradesh	3	Jawahar Lal Nehru Krishi Vishwavidyalaya, Jabalpur
		Madhya Pradesh Pashu Chikitsa Vigyan Vishvavidalaya, Civil Lines, Jabalpur
		Rajmata VRS Agricultural University, Gwalior

Maharashtra	6	Dr. Balaesahib Sawant Konkan Krishi Vidypapeeth, Dapoli, Ratnagiri
		Dr. Punjabrao Deshmukh Krishi Vidyapeeth, Krishinagar, Akola
		Mahatma Phule Krishi Vidyapeeth, Rahuri
		Marathwada Agricultural University, Parbhani
		Maharastra Animal and Fisheries Sciences University, Nagpur
Deemed to be		*Central Institute of Fisheries Education, Mumbai-400061, Maharashtra*
Manipur	1	Central Agricultural University, Imphal
Nagaland	1	Nagaland University, Medizipherma, Nagaland
Orissa	1	Orissa University of Agriculture & Technology, Bhubaneshwar
Punjab	2	Punjab Agricultural University, Ludhiana
		Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana
Rajasthan	3	Maharana Pratap University of Agriculture & Technology, Udaipur
		Swami Keshwanand Rajastahn Agricultural University, Bikaner
		Rajasthan University of Aeterinary & Animal Sciences, Bijay Bhavan Palace Complex, Bikaner
Tamil Nadu	2	Tamil Nadu Agricultural University, Coimbatore
		Tamil Nadu Veterinary & Animal Sciences University, Chennai
Uttar Pradesh	9	Chandra Shekhar Azad University of Agriculture & Technology, Kanpur
		Narendra Dev University of Agriculture & Technology, Faizabad
		UP Pandit Deen Dyal Upadhaya Veterinary and Animal Sciences University, Mathura
		Sardar Vallabh Bhai Patel University of Agriculture and Technology, Meerut
		Manyavar Shri Kanshiram Ji University of Agriculture & Technology Banda, Uttar Pradesh
Deemed to be		*Allahabad Agricultural Institute, Allahabad-211007, Uttar Pradesh*
		Indian Veterinary Research Institute, Izatnagar, Bareilly-243122, Uttar Pradesh
Central Universities		Banaras Hidu University, Varanasi, Uttar Pradesh
		Aligarh Muslim University, Aligarh, Uttar Pradesh
Uttarakhand	2	Govind Ballabh Pant University of Agriculture & Technology, Pantnagar
		University of Horticulture and Forestry, Ranichauri, Tehri Garhwal
West Bengal	4	Bidhan Chandra Krishi Vishwavidyalaya, Mohanpur, Nadia
		Uttar Banga Krishi Vishwavidyalaya, Coach Bihar
		West Bengal University of Animal & Fishery Sciences, Kolkata
Deemed to be		*Vishwa Bharti, Shantiniketan, West Bengal*
Total	61	

In the 11th Five-Year Plan, 51 state agricultural universities, 5 deemed to be universities, 1 central agricultural university, 4 CUs with agricultural faculty.

Appendix 3: Agricultural Research Priorities by Sector and Themes

Sector	Priority Research Themes
1. Crops	1. Crop varieties for • Tolerance to abiotic and biotic stresses • Improving crop yield ceiling in irrigated areas • Better product quality, nutrition, and value addition • Dual-purpose (food and fodder) crops 2. Short duration varieties of rice and wheat to incorporate other crops, especially legumes, in cropping systems 3. Diversifying the production system 4. Improving input use efficiency through integrated crop management, integrated pest management (IPM), integrated plant nutrition management, precision farming, and so on 5. Improving cropping system for higher yields, pest management, natural resource conservation, and integration with livestock and trees 6. Sustainable seed and technology transfer 7. Small farm mechanization
2. Horticulture	1. Postharvest handling, value addition through processing and storage 2. IPM and integrated nutrient management (INM) in orchards, vegetables, and floriculture 3. Improving root stocks and rapid plant propagation methods in fruit trees 4. Integrated management for off-season vegetables, flowers, and periurban cultivation 5. Varieties for better quality, nutrition, shelf-life, and suitable for processing 6. Protected cultivation of vegetables and flowers 7. Development of arid (hot and cold) horticulture
3. Livestock including poultry	1. Technological opinions for sustainable crop–livestock system 2. Improving nutrition through • Quality of crop residues and removing antinutritional factors • Strategic supplementation • Improved varieties of fodder crops and feed balance 3. Animal health • Epidemiology and diagnosis of and vaccine production for major diseases based on biotechnology • Disease–nutrition interactions • Genetic resistance to major diseases 4. Characterization and improvement of local breeds through selective breeding 5. Factors influencing adoption and impact of improved technologies 6. Market development, product processing, and biosafety of products with focus on smallholders 7. Socioeconomics and environmental impact of crop–livestock systems, including pastoral system.
4. Fisheries	***Coastal*** 1. Sustainable management of coastal systems and marine protected areas 2. Sustainable management of marine shrimp farming (feed, nutrition, health, and seed distribution), including effluent management 3. Crab culture and ornamental fish ***Inland*** 4. Genetic improvement for growth enhancement and disease resistance 5. Fish health management, particularly for intensive culture of fish and crustaceans 6. Deepwater rice-fish, freshwater prawn 7. Integrated fish farming and open water culture-based fishery 8. Cold fish–water culture ***General*** 9. Postharvest issues and biosafety of seafood products 10. Socioeconomic issues, environmental impact analysis, and institutional issues of aquatic resources and aquaculture

5. Forestry	1. Sustainable management of second-growth forest 2. Inventorying, evaluation, and development of forest resources 3. Tree and forest health management 4. Promotion and management of agroforestry 5. Improvement of medicinal and aromatic plants 6. Market development for nontimber and minor forest products 7. Policy and institutional issues in management of forests 8. Ecotourism and landscape forestry
6. Natural resources management	1. Conservation of genetic (crop, livestock, fish, tree) water and land resources 2. Improving efficiency in distribution and use of irrigation water (policy, technology, and institutional issue) 3. Technological and institutional options for harvesting and use of rainwater (for example, watershed management) 4. Sustainable land use, organic recycling, and soil fertility management 5. Reclamation of degraded/sodic lands, control/management of saline and arsenic-contaminated water
7. Genetic resources enhancement and agrobiodiversity conservation	1. Plant Genetic Resources (PGR) conservation and improvement 2. Livestock selection and improvement (includes fisheries) 3. Microbial functional agrobiodiversity 4. Biosafety issues, policy, genetically modified organisms, intellectual property rights
8. Socioeconomics and policy	1. Poverty mapping and investment priorities 2. Market integration and trade liberalization with focus on smallholders 3. Risk management 4. Empowerment of women and labor migration 5. Policy and institutional aspects of agricultural research and development

Source: Recommendations of working group farmed during the expert consultation.

Appendix 4: List of Field Trials of Genetically Modified Food Crops Being Conducted by Public Research Institutions

Source: Prepared by Dr. P. Anand Kumar in consultation with Dr. Manju Sharma for National Academy of Agricultural Sciences brainstorming session on "Biosafety Assurance for GM Food in India."

IARI=Indian Agricultural Research Institute; TNAU= Tamil Nadu Agricultural University; UAS= University of

S. No.	Crops	Year	Institute	Traits
1	Brinjal	2006	Sungro Seeds, New Delhi	Insect resistance
2	Brinjal	2006	Mahyco, Mumbai	Insect resistance
3	Cabbage	2006	M/s Nunhems, Gurgaon	Insect resistance
4	Cauliflower	2006	Sungro Seeds, New Delhi	Insect resistance
5	Cauliflower	2006	M/s Nunhems, Gurgaon	Insect resistance
6	Corn	2006	Monsanto, Mumbai	Insect resistance
7	Okra	2006	Mahyco, Mumbai	Insect resistance
8	Rice	2006	Mahyco, Mumbai	Insect resistance
9	Tomato	2006	Mahyco, Mumbai	Insect resistance
10	Okra	2007	Mahyco, Mumbai	Insect resistance
11	Rice	2008	Bayer Bioscience Pvt. Ltd.	Insect resistance
12	Tomato	2008	Avesthagen Ltd.	Nutritional quality
13	Corn	2008	Monsanto India Ltd.	Insect resistance, Herbicide tolerance
14	Brinjal	2009	Bejo Sheetal Seeds, Jalna	Insect resistance
15	Corn	2009	Pioneer Overseas Corporation	Insect resistance, Herbicide tolerance
16	Corn	2009	Dow AgroSciences	Insect resistance
17	Rice	2009	Bayer Bioscience	Insect resistance
18	Rice	2009	Mahyco, Jalna	Insect resistance, Herbicide tolerance
19	Rice	2010	E.I. DuPont	Heterosis
20	Rice	2010	Bayer Bioscience	Insect resistance
21	Rice	2010	Metahelix Life Sciences	Insect resistance
22	Rice	2010	BASF India Ltd.	Insect resistance
23	Maize	2010	Pioneer Overseas Corporation	Insect resistance, Herbicide tolerance
24	Corn	2010	Dow AgroSciences	Insect resistance
25	Corn	2010	Syngenta Biosciences	Insect resistance

Agricultural Sciences; IIVR= Indian Institute of Vegetable Research; NRCPB= National Research Centre on Plant Biotechnology

Appendix 5: A List of Field Trials of Genetically Modified Food Crops Being Conducted by Private Companies and Research Institutions

S. No	Crops	Year	Institute	Traits
1.	Brinjal	2006	IARI, New Delhi	Insect resistance
2.	Castor	2006	Directorate of Oilseeds Research, Hyderabad	Insect resistance
3.	Groundnut	2006	International Crops Research Institute for Semi-Arid Tropics, Hyderabad	Virus resistance
4.	Potato	2006	Central Potato Research Institute, Shimla	Fungal resistance
5.	Rice	2006	IARI, New Delhi	Insect resistance
6.	Rice	2006	TNAU, Coimbatore	Disease resistance
7.	Tomato	2006	IARI, New Delhi	Virus resistance
8.	Brinjal	2007	UAS, Bangalore	Insect resistance
9.	Brinjal	2007	TNAU, Coimbatore	Insect resistance
10.	Potato	2009	Central Potato Research Institute, Shimla	Tuber sweetening
11.	Chickpea	2009	International Crops Research Institute for Semi-Arid Tropics, Hyderabad	Abiotic stress tolerance
12.	Sorghum	2009	National Research Center for Sorghum, Hyderabad	Insect resistance
13.	Watermelon	2010	Indian Institute of Horticultural Research	Virus resistance
14.	Tomato	2010	Indian Institute of Horticultural Research	Virus resistance
15.	Tomato	2010	IIVR, Varanasi	Insect resistance
16.	Tomato	2010	NRCPB, New Delhi	Fruit ripening
17.	Papaya	2010	Indian Institute of Horticulture Research	Virus resistance
18.	Sugarcane	2010	Sugarcane Breeding Institute	Insect resistance
19.	Sorghum	2010	Central Research Institute for Dryland Agriculture	Abiotic stress tolerance
20.	Groundnut	2010	University of Agricultural Sciences, Bangalore	Abiotic stress tolerance
21.	Mustard	2010	NRCPB, New Delhi	Abiotic stress tolerance
22.	Mustard	2010	University of Delhi South Campus, Delhi	Heterosis

Source: Prepared by Dr. P. Anand Kumar in consultation with Dr. Manju Sharma for National Academy of Agricultural Sciences brainstorming session on "Biosafety Assurance for GM Food in India."

IARI=Indian Agricultural Research Institute; TNAU= Tamil Nadu Agricultural University; UAS= University of Agricultural Sciences; IIVR= Indian Institute of Vegetable Research; NRCPB= National Research Centre on Plant Biotechnology

References

APAARI (Asia Pacific Association of Agricultural Research Institutions). 1996. *Agricultural Research Priorities in South Asia*. New Delhi, India

________. 2002. *Agricultural Research Priorities for the Asia-Pacific Region: A Synthesis*.

APAARI, ICRISAT (International Crops Research Institute for Semi-Arid Tropics), and NCAP (National Center for Agricultural Economics & Policy Research). 2005. *Research Need Assessment and Agricultural Research Priorities for South and West Asia*. Proceedings of a workshop held at ICRISAT, October 7–8, 2004. New Delhi, India

Beintema, N. M., and G.-J. Stads. 2008. *Agricultural R&D Capacity and Investments in the Asia-Pacific Region*. Research Brief No. 11. Washington, DC: International Food Policy Research Institute.

Byerlee, D., and G. E. Alex. 1998. *Strengthening National Agricultural Research systems: Policy, Issues and Good Practice*. World Bank. Washington DC

Centennial Group. 2011. *India 2039: Transforming Agriculture*.

Central Statistical Organization, 2011. National Accounts Statistics, Central Statistics Organization. Ministry of Stastics and Program Implementation.http://mospi.nic.in

Chand, R. 2012. ICAR Vision 2050. Presentation Made in the Knowledge Meet: Meeting of AU Vice. Chancellors and ICAR Directors. August 21–22. New Delhi, India: National Center for Agricultural Economics and Policy Research. www.ncap.res.in/upload_files/Vision_Discussion.pdf.

European Initiative on Agricultural Research for Development (EIARD). 2007. Impact Assessment and Evaluation in Agricultural Research for Development. *Agricultural Systems*, Vol 78(2), pp 329-336

________. 2011. *Policy Brief: Making ARD More 'Pro-Poor.'*

European Nanotechnology Gateway. 2006, April. Nanotechnology in Agriculture and Food, www.nanoforum.org.

Evenson, R. E., C. E. Pray, and M. W. Rosegrant. 1999. *Agricultural Research and Productivity Growth in India*. Research Report 109. Washington, DC: International Food Policy Research Institute.

GFAR (Global Forum for Agricultural Research). 2010. *Transforming Agricultural Research for Development.* Report by the Global Author Team.

GOI (Government of India) 2012a. Quick Estimates of National Income, Consumption Expenditure, Savings and Capital Formation. Press Information Bureau. Jan 31, 2012. New Delhi, India.
http://mospi.nic.in/mospi_new/upload/nad_press_release_31jan12.pdf

______ 2012b. Provisional Population Tables- Census of India 2011. Ministry of Home Affairs. January 2012. New Delhi, India.
http://www.censusindia.gov.in/2011-prov-results/indiaatglance.html

G HI (Global Hunger Index) 2008. The Challenge of Hunger: Taming Price Spikes and Excessive Food Price Volatility. IFPRI & Welt Hunger Hilfe and Concern Worldwide; October 2011. Washington DC, USA.

Hall, A., N. Clark, and R. V. Sulaiman. 2000. *Coping with New Policy Agencies for Agricultural Researches: The Role of Institutional Innovations*. Policy Brief 13. Delhi, India: National Center for Agricultural Economics and Policy Research.

Hall, A., M. V. K. Sivamohan, N. Clark, S. Taylor, G. Bockett. 2001. "Why Research Partnership Really Matter: Innovation Theory, Institutional Arrangements and Implications for Developing New Technology for the Poor." *World Development* 29(5): 783–797.

Helmut Kaiser Consultancy, Study: Nanotechnology in Food and Food Processing Industry Worldwide 2003-2006-2010-2015. Helmut Kaiser Consultancy (2004). This is a study on nanofoods which can be purchased from the website. www.hkc22.com/nanofood.html

HKA (Haryana Kisan Ayog). 2012. Draft Agriculture Policy for Haryana, Haryana Krishi Ayog, Chaudhary Charan Singh Haryana Agricultural University, Hissar, Haryana State, India

IARI (Indian Agriculture Research Institute). 2012. Golden Jubilee Address by Prime Minister.
ICAR (Indian Council of Agricultural Research). 1988. *Report of the ICAR Review Committee*. GVK Rao Committee.
________. 2004. *Consultancy, Contract Research and Training in ICAR*, Johl Committee Report.
________. 2005. *Report of the ICAR Reorganization Committee*. Mashelkar Committee.
________. 2009. *Technologies for Commercialization and Adoption*.
________. 2011. *ICAR Vision 2030*.
________. 2012. *Annual Report 2011–2012*. Department of Agricultural Research Education
ILAC (Institutional Learning and Change). 2008. Participatory decision-making: The core of multi-stakeholder collaboration. Brief 19. Netherlands
________. 2010. *An Accountability Framework for Technology Innovations*. ILAC Brief 24. Netherlands
India, Department of Agriculture and Cooperation. 2012. *State of Indian Agriculture 2011–2012.* Delhi, India: Ministry of Agriculture, Department of Agriculture and Cooperation.
India, Ministry of Agriculture. 2000. *National Agricultural Policy*. Delhi, India: Department of Agriculture and Cooperation.
________. 2007. *National Policy for Farmers.* Delhi, India: Department of Agriculture and Cooperation, Ministry of Agriculture.
India, Planning Commission. 2004. *Report of Swaminathan Task Force on Biotechnology*. Delhi, India: Planning Commission.
________. 2005. *Report of the Task Group on Revamping and Refocusing of National Agricultural Research (Swaminathan Committee).* Delhi, India: Planning Commission.
________. 2011a. *Approach Paper to the 12th Five Year Plan*. Delhi, India: Planning Commission.
________. 2011b. *Economic Survey 2011–2012*. Delhi, India: Planning Commission.
ISCA (Indian Science Congress, Ahmedabad). 2001. PM's Address to the Indian Science Congress at Ahmedabad.
Jha, D. 2002. Agriculture Research Policy: Imperatives for 10th Plan Agriculture System, India *Agriculture Situation in India*, pp. 247–258.
Jha, D., and S. Kumar. 2005. *Research Resource Allocation in Indian Agriculture*. Policy Paper 23. Delhi, India: National Center for Agricultural Economics and Policy Research.
Jha, D., P. Kumar, Mruthyunjaya, S. Pal, S. Selvarajan, and A. Singh. 1995. *Research Priorities in Indian Agriculture*. Policy Paper No. 3. Delhi, India: National Center for Agricultural Economics and Policy Research.
Joshi, P. K., S. Pal, P. S. Birthal, and M. C. S. Bantilan. 2005. *Impact of Agricultural Research-Post Green Revolution Evidence from India,* NCAP-ICRISAT
Kalpana Sastry, R., H. B. Rashmi, N. H. Rao, and S. M. Ilyas. 2010. "Integrating Nanotechnology into Agri-Food Systems Research in India: A Conceptual Framework." *Technology Forecasting Social Change* 77: 639–648.
Laxmi, T., P. S. Janaki Krishna, and G. Pakki Reddy. 2007. "Changing Paradigms in Agricultural Research." *Outlook on Agriculture* 36(2): 119–125.
Mruthyunjaya and P. Kumar. 2010. *GCARD Regional Review for Asia Pacific, South Asia Report*. APAARI, ADB, & GFAR. November 2010.
Mruthyunjaya and S. Pal. 1999. "Agricultural Research Priorities for South and West Asia." In *Agricultural Research Priorities for the Asia-Pacific Region: A Synthesis*. APAARI, New Delhi. India..
Mruthyunjaya and P. Ranjitha. 1998. "The Indian Agricultural Research System: Structure, Current Policy Issues and Future Orientation." *World Development* 26(6): 1089–1101.
Mruthyunjaya, S. Pal, and R. Saxena. 2003. *Agricultural Research Priorities for South Asia*. Policy Paper 20. Delhi, India: National Center for Agricultural Economics and Policy Research.
Mruthyunjaya, L. M. Pandey, and A. K. Jha. 2004. "Research Needs Assessment and Prioritization of Agricultural Research for Development: India." In *Research Needs Assessments and Agricultural Research Priorities for South and West Asia*. Proceedings of a workshop held at International Crops Research Institute for Semi-Arid Tropics, October 7–8, 2004, Hyderabad, India.

Mruthyunjaya, S. Pal, R. Saxena, and A. K. Jha. 2003. *Convergence of the Macro and Micro Level Priorities for Agricultural Research.* NATP PME Notes 13. Delhi, India: National Center for Agricultural Economics and Policy Research.

NAARM (National Academy of Agricultural Research Management) and IAMR (Institute of Applied Manpower Research). 2012. *Human Capital Requirements in Agriculture and Allied Sectors*. IAMR Report 1/2012.

NAARM and TAAS (Trust for Advancement of Agricultural Sciences). 2010. *National Dialogue on Building Leadership in Agricultural Research Management: Concern and Future Strategy*. Proceedings and recommendations of the conference..

NAAS (National Academy of Agricultural Sciences). 2002. *Scientists' Views on Good Governance of an Agricultural Research Organization.* New Delhi, India.

________. 2009. *State of Indian Agriculture.* New Delhi, India.

ODI (Overseas Development Institute). 2007. *Opinion 86: Funding Agriculture: Not How Much But for What?*

Pal, S., and D. Byerlee. 2003. *The Funding and Organization Agricultural Research in India: Evolution and Emerging Policy Issues.* Policy Paper 26. Delhi, India: National Center for Agricultural Economics and Policy Research.

Paroda, R. S. 2002. *Change Is Difficult But Change We Must: O&M in Agricultural Research.* New Delhi, India: National Academy of Agricultural Sciences.

Paroda,R.S., and Mruthyunjaya. 1999. *NARS in the Asia Pacific Region: A Perspective*. Bangkok, Thailand: APAARI, Food and Agriculture Organization of the United Nations, RAPA (Regional office for Asia and the Pacific).

Pental, D. 2012. A ban on the use of crops with transgenic traits is unscientific and India needs new technologies to raise farm yields, Economic Times, June 14, 2012.

Plucknett, D. L. 1993. *Science for Agricultural Transformation.* Lecture Series No. 1. Washington, DC: International Food Policy Research Institute.

Pray, C. E., and L. Nagarajan. 2012. *Innovation and Research by Private Agribusiness in India*. Discussion Paper 0118. Washington, DC: International Food Policy Research Institute.

Rajeswari, S. R. 1999. "Professionalization and Evaluation: The Case of Indian Agricultural Research in Knowledge." *Technology and Policy* 2(4): 69–96.

SAARC (South Asia Association for Regional Cooperation). 2008. "SAARC Agricultural Vision 2020." Mimeo.

Singh, A. 2011. "The Changing Landscape of Public Expenditure and Investments in Agriculture: Implications for Growth Trajectory." *Indian Journal of Agricultural Economics* 66(3, July–Sept): 301–313.

Singh, R. B. 2011. *Towards an Evergreen Revolution: The Road Map.* New Delhi, India: National Academy of Agricultural Sciences.

Spielman, D. J., and J. Lynam. 2010. *Design Elements for Agricultural Research within an Agricultural Innovation System's Framework: Evidence from and for Africa*. Proceedings of conference on The Second Science with Africa—June 2-4, 2010, pp. 45–56. Addis Ababa, Ehtiopia

Stads, G. J., and M. Rahija. 2012. *Public Agricultural R&D in Bangladesh, India, and Nepal: Investment and Capacity Trends.* Agricultural Science Technology Indicator. Washington, DC: International Food Policy Research Institute.

Sud, S. The farm sector is starting to feel the pinch of climate change a quick and early adoption of ICT is imperative. Business Standard, May 16, 2012.

UNDP (United Nations Development Program 2011. Human Development Report 2011. New York, USA

UNICEF n.d. Country Indicators. http://www.unicef.org/infobycountry/india_statistics.html

World Bank. 2008. *World Development Report: Agriculture for Development*. Washington, DC.

Photo Credits for the cover page:

1. Vaishali Dassani, IFPRI and 2. Divya Pandey, IFPRI