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Prioritization of Demand-driven Agricultural Research for Development in South-Asia

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Prepared for

International Food Policy Research Institute
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Asia-Pacific Association of Agricultural Research Institutions
(APAARI)

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APAARI	Asia-Pacific Association of Agricultural Research Institutions
APP	Agricultural Perspective Plan
AR4D	Agricultural Research for Development
ARI	Agricultural Research Institute
BARC	Bangladesh Agricultural Research Council
CGIAR	Consultative Group on International Agricultural Research
DAC	Department of Agriculture and Cooperation
DARE	Department of Agricultural Research and Education
F&V	Fruits and Vegetables
GCARD 1 & 2	Global Conference on Agricultural Research for Development 1 & 2
GDP	Gross Domestic Product
GM	Genetically Modified
HRD	Human Resources Development
ICAR	Indian Council of Agricultural Research
ICT	Information and Communications Technology
IP	Intellectual Property
IPM	Integrated Pest Management
IPR	Intellectual Property Rights
MoA	Ministry of Agriculture
MoAC	Ministry of Agriculture and Cooperation
NAAS	National Academy of Agricultural Sciences
NAP	National Agricultural Policy
NARC	Nepal Agricultural Research Council
NARDF	National Agriculture Research and Development Fund
NARS	National Agricultural Research system
NATP	National Agricultural Technology Project
NCAP	National Centre for Agricultural Economics and Policy Research
NFP	National Policy for Farmers
NGO	Non-Government Organization
PME	Priority Setting, Monitoring, and Evaluation
PPP	Purchasing Power Parity
QPM	Quality Protein Maize
R&D	Research and Development
R–E–F–M	Research–Extension–Farmer–Market
SAARC	South Asia Association for Regional Cooperation
SAC	SAARC Agricultural Centre
SAU	State Agricultural University

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, 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 of 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.

Executive Summary

South Asia is home to 1.6 billion people, most of whom live in rural areas. Notwithstanding significant economic progress in recent years, the region has the highest concentration of the world's hungry and poor, more than Sub-Saharan Africa. Agriculture dominated by smallholders is important to the economies and to the livelihoods of the region's people. Although the agricultural growth rate has improved in the last few years, it has fluctuated and been less than the target fixed by the respective countries. The vast majority of South Asia's rural poor depend on the production of rainfed crops, livestock, forestry, and or casual, informal employment for their livelihoods. To provide a pathway out of poverty and to reduce a widening rural–urban income gap, a revival of the agricultural sector is urgently needed. Agricultural research as part of the Green Revolution was a major contributor to agricultural productivity increases across the globe including in South Asia. The Green Revolution has now waned, and new and more complex challenges—such as adaptation to climate change and price volatility—have emerged in recent years to slow or stagnate agricultural production. Unfortunately there is a widespread feeling that agricultural research for development (AR4D) in terms of greater and stable investment is being neglected in the region, except in India. Realizing this, the Global Conference on Agricultural Research for Development (GCARD 1) has conducted a study to analyze the situation and form an AR4D action plan for the region.

The study covers three South Asian countries—Bangladesh, India, and Nepal—which together form nearly 90% of the region's population. These countries share common concerns and have some unique concerns that hinder them from optimizing returns from investments and attaining a higher and inclusive agricultural growth trajectory. The present study analyzes the concerns particularly in AR4D and suggests a strategic plan for accelerated and inclusive growth within and among the countries through increased regional cooperation and collaboration. It prioritizes agricultural research investments for the study countries, and South Asia as a whole, keeping in view the structural, institutional, funding, and technology delivery issues. We prepared the country reports first after a detailed review of agriculture and its subsectors and formal and informal discussions with all concerned, including specially organized, well-attended individual country dialogue meetings involving representatives of all stakeholder categories. Based on the country reports, we prepared a synthesis report, highlights of which follow.

In the wake of stagnating agricultural productivity and worsening food and nutritional security during the 1990s, the study countries formulated specific agricultural policies covering various subsectors of agriculture including agricultural research. Some cross-cutting policies bearing on agriculture were also formulated around this time. In planning, they are generally compatible and synergistic, but show little coordination and convergence during implementation. In addition, whereas the plans are ambitious and well envisioned, there is a large gap between plans/policies and implementation on account of weaknesses in institutional capacity, irregular and inadequate funding, highly depleted human resources with limited skills, weak accountability in the system, and weak monitoring and evaluation practices.

Although agricultural policies in the study countries stress AR4D, they give a mandate to the national agricultural research systems (NARSs) to alleviate poverty and increase the productivity, profitability, sustainability, employment, and livelihood security of small farmers, particularly those located in harsh ecologies, and to empower women and youth. Budgetary support to AR4D is inadequate and variable or uncertain, particularly in Bangladesh and Nepal. Private-sector involvement is less or lacking, particularly in Bangladesh and Nepal. The agricultural research intensity ratios are far below the ratios prevailing even in some of the developing countries. Apart from budgetary and funding concerns, the NARSs demonstrate major structural and institutional, agricultural education and human resources development (HRD), and technology delivery concerns and weaknesses in AR4D.

As regards structural issues and weaknesses, although the countries' NARSs follow varying forms of the National Agricultural Research Council (NARC) model with declared autonomous status on paper to function as independent research bodies, all face a variety of hassles and stresses relating to functional autonomy with respect to budget making; resource allocation; rules for expenditure; recruitment, selection, and assessment; personnel policy; political interference; no centralized or uniform acts or rules covering all agricultural research institutes; and so on. Such hassles and stresses have lessened the efficiency and impact of the NARSs. The NARSs badly require functional autonomy through de-bureaucratization, professionalization, science-friendly rules and procedures, better service conditions, and sufficient incentives for encouraging merit and performance. India has one of the largest NARSs in the world, but its size, spread, and diversity constrain its performance, besides its insufficient functional autonomy. A review of size, spread, and diversity may be needed for appropriate integration, consolidation, and amalgamation.

The institutional issues affecting the performance of the NARSs include weak prioritization, monitoring, and evaluation mechanisms and practices; insufficient and ambiguous decentralization of power; declining human resources both in number and quality; lack of innovative schemes to engage available national skill and expertise including eligible retired faculty; lack of good leadership and faulty selection of senior research leaders; lack of manpower planning; creating new institutions without additional manpower and infrastructure resources; restrictions in recruitment; inadequate faculty development and training programs; poor emphasis on agricultural education; weak communication and publicity skills; limited national, regional, and international linkages and partnerships, cooperation, and collaboration; lack of progressive policies including clear-cut intellectual property rights (IPR) policy to actively engage the private sector in AR4D; and others.

Some of the major funding issues confronting the NARSs are inadequate and erratic funding; no systematic planning and prioritization; limited innovations in mobilizing new sources of funding; not being able to follow best fund use practices like use of an online financial management system; lack of simplified rules and procedures suitable to AR4D; untimely release of funds; outdated procedures like keeping the distinction between plan and nonplan expenditures; limited core funding from the government; and very low budgetary support to research contingencies and operational costs.

The major technology delivery issues facing the NARSs include the near collapse of the public extension system; inadequate funding of technology delivery activities constraining to strengthen manpower particularly in horticulture, livestock, poultry, fisheries, postharvest management and agricultural engineering, agribusiness, and IPR; inadequate knowledge and use of new technologies including information and communications technology (ICT); mobility and e-connectivity constraints; not linking donor funding with development activities; and so on. Several promising extension models exist across the countries—such as the krishi vigyan kendras and the agricultural technology management agencies in India—which need testing and use in other countries. Research in the NARSs on extension methodology has also weakened over the years; such research is needed particularly to handle frontier technologies and relations with the private sector.

The Asia-Pacific Association of Agricultural Research Institutions (APAARI) and national and international organizations have pioneered several studies to prioritize agricultural research in the region. They use both supply-driven and demand-driven analytical approaches, also employing wide stakeholder consultations; sometimes hybrid approaches are used. Such exercises are more frequent in India than in Bangladesh and Nepal. But the trend toward using objective, formal exercises is visible even in Bangladesh and Nepal—a positive development. Refinement of such exercises is possible and needs consideration in the future.

Many new technologies with the potential of scalability are appearing on the horizon and should be used extensively after careful evaluation. They include nanotechnology, biotechnology, advanced processing and packaging technology, biorisk management technologies, resource conservation technologies, mechanical technologies, and information, communication, and remote-sensing technologies. In some cases they have proved their worth but political systems and the public do not accept them because of doubts about their human and environmental safety. Therefore these new technologies need to be deployed with open and transparent decision making only after rigorously establishing their credentials on those two important counts. Further, these technologies are raising new issues for the NARSs related to economies of size, international collaboration, public–private linkages, IPR issues, regulatory issues, commercialization issues, technology transfer issues, and funding issues, among others. Such issues cannot be overlooked.

Our strategic plan identifies demand-driven commodity, resources management, structural, institutional, funding, and technology delivery priorities for accelerated and inclusive growth in the region as well as in the individual countries. The plan underscores the importance of regional research alliances and cooperation for significant gains. This has become especially necessary as spillover effects of yield-improvement technologies are significantly decreasing under the new IPR regime emerging in the world and developed countries are shifting research focus toward value and quality improvements rather than yield improvements, creating a kind of technology orphan condition in developing countries. For South Asia as a whole, then, the strategic plan includes increasing funding support by 2-3 times of the present level; stress on commodity and resources management research; strengthening the governance systems and skills; partnership internally, regionally and globally; an effective technology delivery system, and improved soft skills to enhance the technology development and dissemination, efficiency, credibility and visibility of NARSs; followed by strengthening the the value chain and market integration with agricultural engineering inputs including rural energy, and small farmer mechanization.

1. Introduction

1.1 The Economy

South Asia is home to 1.6 billion people most of whom (around 75%) live in rural areas. South Asian countries have made remarkable progress in economic growth (about 6.5% annual GDP growth annually) and poverty reduction since the turn of the millennium (Table 1). But the region still houses close to half the world's poor (more than 420 million) and undernourished (299 million) (Mittal and Sethi 2009). The percentage of the population that suffers from hunger varies from 17% in Nepal to 30% in Bangladesh. South Asia has the world's largest concentration of poor people in addition to significant gender disparities and political, ethnic, religion related conflicts. In 2008, 571 million South Asians lived on less than US$1.25 per day—a global measure of extreme poverty. According to the 2011 Global Hunger Index, the highest GHI score, 22.6%, occurred in South Asia, exceeding even the Sub-Saharan Africa score of 20.5%. Poverty and malnutrition in the region are

Table 1—Basic socioeconomic indicators for South Asia

Indicator	Period	Bangladesh	India	Nepal
1. Population (millions)	2010	152.5	1,210	29.3
2. Population density (people/square kilometer)	2010	1,099	382	200
3. Urban population (% of total population)	2010	28.1	30	17
4. Gross national product (in billion U.S. dollars)	2010	94.0	1,253	12.85
5. Average annual GDP growth rate (%)	2001–10	6.7	6.9	3.9
6. Real per capita GNP (2005 international U.S. dollars)	2010	1,940	3,620	1,260
7. Export of goods and services as percentage of GDP	2010	19.43	21.54	9.75
8. External debt as percentage of GNP	2010	22.81	17.65	23.4
9. Human Development Index	2010	0.500 (146)	0.547 (134)	0.458 (157)
10. Global Hunger Index	2011	24.5	23.7	19.9
11. People below poverty line (%)	2010	29.9	31.5	32
12. Share of agriculture in GDP (%)	2010	20	13.0	35
13. Share of population engaged in agriculture (%)	2010	47	50	65
14. Average size of holding (hectares)	2010	0.5	1.23	0.8
15. Adult literacy (%)	2006–07			
Male		60	75.2	71.1
Female		49.8	50.8	45.4

GDP = gross domestic product; GNP = gross national product.

not only widespread, more than Sub-Saharan Africa, but also increasingly concentrated in lagging rural areas (Stads and Rahija 2012). Given that South Asia has the highest concentration of the world's hungry and poor, and that the condition is not only persistent but worsening on account of food price inflation that affects the poor especially, a special effort under the Global Conference on Agricultural Research for Development (GCARD) process is warranted to analyze the situation and form an action plan to remedy the malady and ultimately alleviate the suffering (Singh 2009). Lele et al. (2010) report that the prospects for reducing poverty quickly are greater in South Asia than in Africa. Thus, making a greater investment in South Asia makes sense, regionally and globally. The exercise at hand is a step in that direction.

1.2 Agriculture

Although a few South Asian countries (for example, India) are described as *transforming* (World Bank 2008), their economies are still dominated by agriculture for livelihood (SAC 2012). Agriculture contributes a third of GDP in Nepal, 20% in Bangladesh, and 13% in India (Table 1). About half the population depends on agriculture for livelihood in India and Bangladesh, whereas in Nepal that percentage is two-thirds. Although the agricultural growth rate has improved in the last four to five years in these countries, it has fallen short of the targeted growth rates fixed by these countries, has been far below the growth rates of other economic sectors, and has fluctuated greatly. In fact, in South Asia growth has been led by the industrial and service sectors, and in Bangladesh and Nepal, the drivers of economic growth are remittances (second-largest source of income after agriculture in Nepal) and exports. Agriculture is dominated by smallholdings (Table 1). The vast majority of the rural poor in these countries depend on the production of rainfed crops, livestock, forestry, or casual, informal (often migratory) employment for their livelihoods (World Bank 2008, 2012a).To provide the rural poor a pathway out of poverty and to reduce the widening rural–urban income gap, the region urgently needs a revival of the agricultural sector combined with rural nonfarm growth. The World Bank predicts that the population of South Asia will reach 2.5 billion by 2050, up from 1.6 billion today. Over the next two decades, demand for higher-value foods will increase as a consequence of a growing upper and middle class, rising incomes, and urbanization and export opportunities, potentially leading to diversification and value addition in agriculture. For example, in South Asia, the projected growth in demand in 2025 exceeds 2% for vegetables, fruits, milk, and meat versus around 1% for cereals and 1.3% for pulses and oilseeds (Mruthyunjaya and Kumar 2010). In Bangladesh, it is reported that domestic consumption pushed by remittances has contributed up to 70% of the economic growth in the past decade (World Bank 2012b). Domestic consumption–led growth is also a reality in India and Nepal (pushed again by remittances). To feed the growing population and address other pressing problems—including climate change, energy crises, and rising and volatile food prices—the region must increase agricultural productivity without delay (Stads and Rahija 2012). Other obstacles to accelerated and inclusive agricultural growth need to be simultaneously addressed. Actions needed include rationalization of subsidies on food, power, irrigation, and fertilizers; investment to strengthen technology, innovation systems, and agro-advisory services; rehabilitation and institutional reform of irrigation systems, market support services, and rural infrastructure; and avoidance of government overregulation of domestic trade, agroprocessing, enterprise size, and land and credit markets (World Bank 2012a). Many commonalities exist in the agro-ecologies, agricultural practices, and agricultural challenges of the South Asian countries that offer unlimited scope for regional consultation and cooperation for accelerating agricultural growth.

1.3 Agricultural Research for Development

A persuasive body of empirical evidence has demonstrated that agricultural research and development has been a major contributor to agricultural productivity increases and poverty reduction around the globe over the past five decades (World Bank 2008; IAASTD 2008). The Green Revolution (stemming from research-based agricultural methods and new technologies) launched in the region in the 1960s by the NARSs was an unprecedented success—it increased productivity, expanded agricultural production, and more than halved the percentage of hungry and poor by 1995. That revolution has now waned (Singh 2009). The region has seen a stagnation or slowing of agricultural productivity in recent years. Food insecurity and poverty, particularly rural poverty—accounting for one-half of the world's hungry and poor and exacerbated by soaring food and fuel prices, the global economic downturn, and climate change–induced vulnerability—have resurfaced as major challenges. Rural–urban and farmer–nonfarmer income divides and fast-declining and -degrading land, water, and biodiversity resources have further aggravated the problem. The resource-poor small farmers who dominate agriculture in these countries and whose farm holdings have become tinier and tinier over the years are the worst hit in this process. All across the subregion, the call for reinvigoration of the agricultural sector has echoed and intensified in recent years. Effective and well-targeted agricultural research and development (R&D) would play a key role (Singh 2009; Stads and Rahija 2012). For this, sharply increased investments in AR4D must be at the top of the policy agenda. In the *Report of the South Asia Group on AR4D in the Asia-Pacific Region* (Mruthyunjaya and Kumar 2010), a threefold to fourfold increase in funding support to AR4D from US$1.6 billion in 2002 to US$4.6 billion (at current prices) is suggested. The South Asian NARSs, although evolved under a similar historical perspective, have different organizational structures, processes, governance, and management weaknesses and are under tremendous pressure to perform and deliver. GCARD 1 deliberated the issues of intensification and diversification of agriculture in the region along with the new role of AR4D and recommended efforts in defining and executing a pro-poor and pro-growth AR4D strategy by collecting more evidence on what has worked in the past, where investments are being made at present, and what priorities should be set for the future. This has become especially important subsequent to GCARD 1 with the effects of climate change on agriculture and the frequent global economic shocks in the form of food price inflationary trends that adversely affect mostly poor people in the region.

1.4 The Study

The study covers Bangladesh, India, and Nepal. Those countries formed about 87% of the total population of South Asia in 2011. India and Bangladesh are classified as transforming countries and Nepal as an agriculture-based economy (World Bank 2008). Out of the three countries, India and Bangladesh are noted for sustained and rapid economic growth; substantial scientific and other human and institutional capacities; a diversity among institutions including civil-society, private-sector, and women's organizations; a free and lively press; a greater density of physical infrastructure; and access to markets (Lele et al. 2010). Nepal is trying hard to accelerate agricultural growth by systematic planning and raising investment in agriculture in general and AR4D in particular (Joshy 2012). Yet massive poverty persists despite the rapid economic growth owing to policy and institutional failures—although there have been a number of scattered successes. Substantial investment has been made in AR4D in South Asia, particularly in India, but the impact of such investment is not what one would expect due to structural and institutional weaknesses among other weaknesses (Mruthyunjaya 2012). In Bangladesh, the trend in agricultural research investment by the national government in the recent past has not been uniform, sustainable, or encouraging. There are, again, structural, institutional, and funding issues that, if addressed, can enhance the capacity of the research and extension system to address priorities (Kabir and Hussain 2012). Nepal, on the other hand, is a small country. It did not suffer major food deficits until the 1980s but since then has become increasingly dependent on cereal imports. In Nepal, the lower agricultural growth rate combined with a very high year-to-year variability is largely responsible for continued food insecurity and widespread poverty (Joshy 2012). The main factors in the agriculture sector's less-than-satisfactory performance are low levels of investment, a lack of appropriate priority setting, and rudimentary infrastructure, in addition to the problems of insurgency and political instability. Joshy (2012) further reports that despite having well-conceived and formulated plans and policies, the country has yet to show a positive effect on the performance of the agriculture sector largely because of a lack of commitment; structural, institutional, and funding issues; and a large gap between plans/policies and implementation. If there exists a willingness in the region to confront tough internal policy and institutional constraints and to form active partnerships internally with programs that are more successful and externally with regional, emerging, international, and advanced countries, then poverty can be reduced substantially in the next 10 to 15 years (Lele et al. 2010). From the preceding observations, it becomes clear that Bangladesh, India, and Nepal share some common concerns, and have some unique concerns, that hinder them from optimizing returns on investments and from attaining a higher and inclusive agricultural growth trajectory. The present study looks at those concerns in agriculture in general and AR4D in particular and presents what we hope is a suitable strategic plan to accelerate faster and inclusive growth.

1.5 Methodology

The present study provides a prioritization of agricultural research investment in South Asia keeping in mind the structural and institutional issues, assesses innovative funding mechanisms, and thus refines GCARD 1's agricultural research agenda for South Asia. To do this, we made a comprehensive analysis of each study country as follows:

1. Reviewed structural, institutional, funding, and technology delivery concerns in AR4D.
2. Included views from the demand side (farmer groups, civil society, and the private sector) through a policy dialogue in each country.
3. Assessed 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 resources use, food production, and trade.
4. Developed a strategic plan for enhanced AR4D prioritization for each country, including recommendations for AR4D research prioritization, structural and institutional reforms, expanded investment sources and mechanisms, and innovative AR4D delivery.

The country reports are prepared with a detailed review of agriculture and its subsectors using secondary information; a recent study of reports and vision documents of governments and other agencies; and our own experience through formal and informal discussions with various organizations, stakeholders, and individuals connected with AR4D, including specially organized individual country dialogue meetings with a total of 119 participants drawn carefully from different stakeholder constituencies such as government and the public sector, civil society and NGOs, the private sector, academia, farmer organizations, and women. The country reports analyze the agricultural situation, policies, and the AR4D system, and form a strategic plan for AR4D and a list of focused, manageable priorities considering current needs of stakeholders.

1.6 Outline of the Synthesis Report

Based on the comprehensive analysis of the AR4D needs of Bangladesh, India, and Nepal and the investment priorities resulting from those needs, as set forth in the country needs assessment reports, a synthesis report is prepared with the following outline:

1. Introduction, objectives, methodology, and chapter outline (section 1)
2. A critical review of key policies and institutions that influence AR4D priority setting, financing, and execution (section 2)
3. A critical review of structures, processes, and issues related to priority setting, financing, and execution (section 3)

4. A synthesis of views on AR4D priority setting, financing, and execution from all the stakeholders (section 4)
5. An assessment of the potential of selected technologies (section 5)
6. A strategic plan for enhancing AR4D in terms of improved research prioritization, expanded sources of funding and investment, and innovative delivery and dissemination of AR4D (section 6) and a brief summing up of the report (section 7)

2. Key National Policies and Institutions That Influence AR4D Priority Setting, Financing, and Extension

2.1 Key National Policies

In the wake of stagnating agricultural productivity and worsening food and nutritional security, the study countries have in the past few years begun crafting formal policies on agriculture and related sectors for increasing and sustaining agricultural growth. For example, Bangladesh formulated the National Agriculture Policy in 1999 and the New Agriculture Policy in 2010. India crafted the National Agriculture Policy in 2000 (India, DAC, 2000) and the National Policy for Farmers in 2007(India, DAC, 2007). Nepal built on the Agricultural Long-Term Perspective Plan (APP), which had been in place since 1995, with the Nepal Agriculture Policy (NAP) in 2004. The NAP is seen as a means to achieve the APP's goals rather than as a new strategic document. The agriculture policies generally apply to subsectors of crops, horticulture, livestock, and fisheries and all the associated input and support services including agricultural research, education and extension, seeds, fertilizer distribution, marketing, and credit. The study countries also have cross-cutting policies bearing on agriculture relating to land use, food, sugar, water, forestry, the environment, fertilizer, energy, industry, mechanization, extension, and others under the respective ministries to address specific issues and contribute to enhanced agricultural growth. As per the country reports, these related policies, dating mostly from the 1990s following national and international developments relating to concerns on food and the environment, were formulated in consultation with and using feedback from all the related ministries, and they are therefore generally compatible and synergistic in terms of their stated objectives, but there was little coordination and convergence at the time of implementation leading to duplication of efforts and less than optimum use of scarce human and financial resources. The Bangladesh country report (Kabir and Hussain 2012) also observed conflicts among some policies during implementation on account of their being formulated by different ministries and at different points in time, and most missed incorporating the emerging climate change effects. The Nepal country report (Joshy 2012) observed that Nepal already has a rich body of plans and policies that are often well envisioned and formulated, but that the main issue is the large gap between plans/policies and implementation on account of weaknesses in planning and institutional capacity, irregular and inadequate funding, human resources with limited skills, weak accountability in the system, and weak monitoring and evaluation mechanisms. The India country report (Mruthyunjaya 2012), after reiterating the same conclusions of the Bangladesh and Nepal reports, further observed an impressive array of government and NARS initiatives with weak implementation and less-than-commensurate returns and system-wide impact.

2.2 Agricultural R&D

The agricultural policies of all three countries invariably emphasize AR4D, but the budgetary support does not match that emphasis, particularly in Bangladesh and Nepal. The policies stress the following: increasing the productivity, profitability, sustainability, exports, employment, income, and livelihood security of, especially, small farmers in harsh ecologies like the dryland, coastal, hill, and mountain regions; technological empowerment of rural women and youth; increasing efficiency in input use; natural resources management; sustainable intensification of farming; diversification with a farming system approach; processing and postharvest management; supply chain management; strengthening AR4D; better governance of research institutions; human resources management; strengthening service- and input-delivery systems and extension services; better coordination with development departments; and more. Except in India and to some extent in Bangladesh in recent years, private-sector involvement in AR4D is insignificant. But the involvement of NGOs is prominent in Nepal and Bangladesh. In fact, as per the changing context and needs, the study country governments have promoted AR4D even before formulating formal agricultural policies, as can be seen in the country reports. The evolution of the agricultural research system's structure and processes differs by country, although Bangladesh and Nepal tried to follow the pattern and processes of the Indian NARS. But such evolutionary changes were slow and mostly ad hoc, which became increasingly inadequate with the changing, complex agricultural context requiring more systematic planning, structure, processes, and funding with supportive and stable policies.

2.3 Funding for AR4D

Although overall growth in AR4D funding was positive from 1996 through 2009, large differences are noted across countries. India witnessed steady growth except for a period of stagnation during 1999 through 2004. The country's public spending in AR4D increased from 929 million purchasing power parity (PPP) dollars in 1996 to 2.276 billion PPP dollars in 2009 (in 2005 constant prices) (Stads and Rahija 2012). However, agricultural research spending slowed to 3.38% in the 1990s from an impressive rate of 5.96% in the 1980s. Although the rate has very marginally improved to 3.48% in the 2000s, a serious concern remains, especially in view of the increasingly capital-intensive nature of agricultural R&D (Singh 2011). The research system now grapples with a much-expanded agenda to address issues such as sustainable management of natural resources, adaptation to climate change, the supply chain, food quality and safety, food price inflation, household food and nutritional security, and poverty reduction. Notwithstanding the steady growth in government funding for AR4D, with the expanded work agenda, more resources will now be needed to meet the needs of the growing population (Pal, Rahija, and Beintema 2012). In Bangladesh and Nepal, which are traditionally dependent on external donor funding, AR4D funding trended much more relatively lower and volatile mostly as a result of the completion of large donor-funded projects. In 2009, Bangladesh invested 126 million PPP dollars and Nepal, 23 million PPP dollars (Stads and Rahija

2012). Closely following the absolute level of spending, another relative but widely used measure of commitment to public AR4D investment across countries called *agricultural research intensity* gauges total public AR4D spending as a percentage of agricultural GDP. Although agricultural research intensity over the years has improved slightly in the study countries with high variability in Bangladesh and Nepal (0.40%, 0.24%, and 0.31% in India, Nepal, and Bangladesh, respectively, in 2009), the measures are much below the ratios prevailing even in some of the other developing countries, such as 1.04% in Brazil, and of course far below levels in developed countries (2.35%). Given the study countries' low intensity ratios, AR4D spending needs to triple or quadruple in the coming years (under the assumption that agricultural output remains unchanged) (Stads and Rahija 2012; Singh 2009).

2.4 Human Resources Development for AR4D

The strength and efficiency of the research systems depends not only on more generous and more stable funding support but also on strong human resources backup. In 2009, a little more than 13,500 full-time equivalent agricultural researchers were active in Bangladesh, India, and Nepal. With more than 11,000 full-time equivalents, India accounted for the lion's share, whereas Bangladesh and Nepal employed about 2,000 and 400 researchers, respectively. The number of agricultural researchers has steadily declined in India and Nepal since the turn of the millennium. It is reported that the Indian agricultural research and education system is growing continuously in size (number of institutions) but that manpower has not kept pace. At several state agricultural universities (SAUs), the number of occupied faculty positions has markedly dwindled, besides suffering from inbreeding (the phenomenon of recruiting the staff mostly from the same region/locality), aging, and declining skills (Singh 2011). Nepal's declining AR4D capacity is largely due to a long-term hiring freeze and the loss of scientists seeking better career opportunities abroad. In Bangladesh, although numbers have steadily increased, many vacancies exist at the Bangladesh Agricultural Research Council (BARC)–affiliated agencies (about 20% of positions are vacant). A program to fill vacant positions, plan for higher degrees, and promote deserving candidates is important (Kabir and Hussain 2012). Another important aspect of human resources is one's qualifications. India's AR4D staff, including the support staff (who assist scientists), are significantly better qualified than the AR4D staff in other countries, although the shares of postgraduate-qualified scientists in Bangladesh and Nepal have steadily increased since 2003 (Stads and Rahija 2012). Despite the slight increase in qualifications, official degree-level training opportunities have been limited in Bangladesh and Nepal, as only about 20% of scientists in those countries have a doctoral degree (Kabir and Hussain 2012; Stads and Rahija 2012). This needs attention. Yet another dimension of agricultural research capacity is the age distribution of scientists. The age imbalances are serious in Nepal as more researchers with postgraduate qualifications are within the older age group (51 to 60) and will retire in the near future (Joshy 2012). Therefore, Nepal needs to prioritize the training and mentoring of more young scientists. Furthermore, Bangladesh and Nepal have a very low proportion of female agricultural scientists, a problem that needs immediate correction to involve South

Asian women in agricultural sciences. With the exception of the SAUs in India, AR4D funding for higher-education agencies is largely spotty and ad hoc. In Bangladesh, higher studies are mostly carried out with the assistance of donor-supported projects. Recently, the Bangladesh government allocated funding to BARC for higher studies leading to an in-country Ph.D. degree, but the program will require further strengthening. In Nepal, no such functional efforts are in evidence.

2.5 Technology Delivery in AR4D

The technology delivery system, along with inputs and supply of services, is weak in all three countries. The public research system in each country develops technologies, assesses them on farmers' fields, refines them if needed, and passes them to the public extension system operated by the departments of agriculture, horticulture, animal husbandry, and fisheries in the Central Government and states (in the case of India) for mass transfer to the farmers. In India, the *krishi vigyan kendras* (at least one in each of 640 districts) are the main institutions under the Indian Council of Agricultural Research (ICAR) for frontline extension. As for public extension, agricultural technology management agencies are functioning in all the districts of the country. The synergy between these institutions is weak as yet. The share of extension expenditure in agriculture GDP has been stagnant (0.15%) for the last two decades (Singh 2011). In Bangladesh, some agricultural research institutes do not even have a technology dissemination division. The Technology Transfer and Monitoring Unit of BARC was created to facilitate primary extension and monitoring of the transfer process, but that unit needs to be made more functional with adequate human resources (Kabir and Hussain 2012). The public extension system has become very weak over the years, resulting in the absence of technical backstopping for farmers. Joshy (2012) reports that the poor performance of Nepal's agriculture sector in the past is a reflection of the ineffectiveness of agricultural extension and training systems in that country owing to the thin spread of junior technicians and junior technical assistants, ineffective frontline extension backup, lack of mobility, and insufficiently equipped offices and service centers. The weaknesses in the study countries' technology delivery systems will be exposed further in the future with the introduction of more knowledge-intensive modern technologies in the diverse subsectors of agriculture (horticulture, livestock, fisheries, agricultural engineering, market intelligence) including the rural nonfarm sector. These technology delivery systems need increased investment, innovation, and institutional and organizational reforms combined with efficient input and service supply to make them more pluralistic, demand driven, and cost efficient.

3. Structure, Processes, Funding, and Technology Delivery in the NARSs of South Asia

The NARSs in the Asia-Pacific region are dynamically heterogeneous and evolving. Since the 1960s, many Asian countries have been consolidating and reshaping their agricultural research operations and systems (Singh 2009). The NARSs around the world follow several models including some combinations of different models. Some of the popular models are the agricultural research council model (India, Bangladesh, and others); the national agricultural research institute model (Latin American countries); the ministry of agriculture (MoA) model (Indonesia, Thailand, and others), and the agricultural research corporation model (Brazilian Agricultural Research Corporation [EMBRAPA]). The region's NARSs could be made stronger by the sharing of strengths, weaknesses, and institutional innovations, such as the establishment of the Krishi Gobishona Foundation in Bangladesh; the agricultural technology management agencies; the *krishi vigyan kendras;* the National Fund of Basic and Strategic Research; Agri Innovate India; National Fund for Basic, Strategic, and Frontier Application Research in Agriculture in India; and the Nepal Agricultural Research and Development Fund (NARDF) in Nepal (SAC 2012).

3.1 Structural Issues

The governments of Bangladesh, India, and Nepal have established agricultural research councils for the management and financing of agricultural research according to their needs and aspirations. The institutional composition of public agricultural R&D in these countries has remained relatively unchanged since the mid-1990s. Although there have been ongoing internal reorganizations, none of the countries has undertaken a fundamental restructuring of its research system (Beintema and Stads 2008). A total of 229 agencies were identified as conducting public AR4D in these countries, including 130 government agencies, 95 higher-education agencies, and four nonprofit agencies. Unsurprisingly, the size and structure of AR4D systems vary greatly by country.

In India, 167 public agencies conduct AR4D, compared with 54 in Bangladesh and just eight in Nepal. Despite differences in size and structure, the organization and coordination of NARSs bear many similarities across countries (SAC 2012). Each country employs a national agricultural research council that coordinates AR4D, sets priorities, and funds schemes and projects. However, the role of such councils as well as the scope of their own autonomy and authority over research institutes varies from country to country and is changing in some cases (Stads and Rahija 2012). In 2009, government agencies represented 59% of agricultural R&D capacity, higher education accounted for about 41%, and the nonprofit sector accounted for less than 1%. The overall shares mask some major cross-country differences. Whereas the government sector is the dominant employer of AR4D staff in Bangladesh and Nepal, higher education employs most researchers in India. In 2009, universities (mostly SAUs) accounted for 57% of Indian agricultural R&D capacity. Nepal is the only country of the three where the nonprofit sector plays a significant role. In 2009, the private sector accounted for about 9% of Nepalese agricultural research capacity. Private-sector involvement is increasing in India, and since the mid-1990s AR4D spending by the private sector has increased fivefold (Pray and Nagarajan 2012). In 2008–2009, the private sector spent 7.8 billion rupees or 0.5 billion PPP dollars (both in 2005 constant prices) on AR4D, accounting for 19% of India's total (public and private) spending on AR4D (Pal, Rahija, and Beintema 2012). Private-sector involvement has increased in Bangladesh in recent years in the seed and fertilizer sectors (Rashid, Ali, and Gisselquist 2012). As for technology commercialization, in Bangladesh, NARS institutes have signed memorandums of understanding with the private sector and NGOs to receive research-generated technology, knowledge, and processes (Kabir and Hussain 2012).

In all three countries, the national agricultural research councils formulate agricultural research policies; set priorities; plan, undertake, coordinate, promote, fund, and evaluate research activities; and institute and promote the transfer-of-technology programs (explicit only in the case of India) related to agriculture and allied sectors. But they have more similarities and some differences in terms of their structure and functioning.

In India, ICAR is an autonomous organization of the government but is part of the Department of Agricultural Research and Education (DARE), which is one of the three departments under the united MoA. It has primary responsibility in research, education, and frontline extension. The executive head of ICAR, called the director general, is ex officio secretary to DARE (for details of existing institutional structure see Mruthyunjaya 2012). The policymaking body in ICAR is the general body of the ICAR Society, chaired by Agriculture Minister of Government of India (highest) and the governing body of ICAR is Chaired by DG, ICAR. The Governing Body functions under the overall guidance of the General Body. ICAR has had an all-India agricultural research service since 1975. The government has constituted an independent Agricultural Scientists Recruitment Board under the MoA to recruit, assess, and promote scientists in ICAR. Such centralized service and recruitment mechanisms are nonexistent in Nepal and Bangladesh. Over the years, ICAR has played a promotional role by serving as the University Grants Commission and providing development grants to the SAUs (varying from 10% to 30% of their total spending) for strengthening agricultural education in the states. ICAR also supports the SAUs in research and frontline extension through the All-India Coordinated Research Project, network projects, *krishi vigyan kendras*, and so forth to an extent of another 20% to 30%. The SAUs consider these supports for AR4D as very valuable, but the dual control over the SAUs by the state on administrative matters and ICAR on technical matters creates stress on the universities to comply with instructions, and in the process the SAUs' performance has become variable. This issue needs attention. Regarding research initiatives, SAUs meekly follow the lead ICAR provides. In view of dwindling financial support and manpower resources in the states, ICAR may have to play a dominant role in the future to strengthen the SAUs as adjunct institutions at the state and zonal levels, with some even sharing ICAR responsibilities in addition to their localized mandates. But that will require massive funding and capacity-building efforts in the SAUs. To ensure a continued cordial relationship between ICAR and the SAUs, greater compliance with the revised Model Act of Agricultural Universities; restraint on opening discipline-based universities; balancing research, education, and extension roles; and maintenance of education and research standards by the SAUs are suggested (Mruthyunjaya 2012). ICAR's efforts in the commercialization of technologies through a multilayer, structured technology management framework with clear-cut IPR rules, including the recent initiative of establishing Agri Innovate India as a company, have started paying dividends, but the framework needs further strengthening with more freedom and flexibility in rules and procedures. The technology commercialization system in the SAUs varies and needs standardization. ICAR, despite its autonomous status, still is not free from inelastic regulations, particularly financial and administrative, as well as from government authority. There is an urgent need to frame rules and procedures suitable to ICAR. ICAR's workforce, scientists as research managers or in administration or finance, may need to realize that their responsibility is to serve science first and bureaucracy later. Another concern is the current size, spread, and the diversity of institutions in ICAR. To fulfill changing needs, over the years ICAR has opened too many institutions of diverse types throughout the country. But it is strongly felt by several review committees that the current size, spread, and diversity is unmanageable and needs downsizing, rationalization, integration, and consolidation with clear mandates. Though private-sector involvement in agricultural research is increasing on account of favorable policies of ICAR, its involvement will improve with still better, progressive policies such as public–private sector partnership; trust and transparency; information sharing; technical advances associated with biotechnology and other frontier sciences; a clear IPR and regulatory regime; and suitable financial, investment, and tax incentives from government (Pray and Nagarajan 2012). To address the political-economic factors, the research system should keep the polity analytically informed. This linkage and capacity is weak in the NARS, and it has to build a lobby to generate political, policymaker, and public support for those who allocate funds to research.

In Nepal, NARC is an autonomous organization within the MoA; it makes policy that the Executive Board implements (SAC 2012). But unlike in India, NARC's primary responsibility is only research. Further, unlike in India where ICAR/DARE submits its program and budget proposals directly to the National Planning Commission, NARC must submit its programs and budget proposals through the Ministry of Agriculture and Cooperation (MoAC), its contact ministry, to be discussed and decided on by the National Planning Commission. Joshy (2012) opines that the existing process of allocating the agricultural research budget through the MoAC needs to be revisited if one wants to see NARC proactive and vibrant. NARC should follow the Indian model of submitting its program and budget proposals directly to the National Planning Commission so that it can better articulate its needs and argue for and get higher funding from the commission; and once the budget is finalized, it may be channeled through the MoAC. To match the Indian model, NARC may have to establish its linkage with the MoAC by having the executive director of NARC become ex officio secretary (research) in the MoAC. The reported advantages of such restructuring include the assured funding from and consistent support of government, addressing the grey area between technology generation and dissemination, faster decision making on implementation of government policies and programs, and enhanced collaboration with government and donors. But another group opposes such restructuring, maintaining that the listed advantages will not be fully possible in the government bureaucracy, and hence it suggests reforming the present structure of NARC by making the Prime Minister the chairman of NARC so that NARC can function truly as an autonomous organization. In 2001, the government introduced a competitive-grant-scheme policy in agricultural research. A separate institution, the National Agriculture Research and Development Fund (NARDF), was established under the MoAC. This agency does not carry out research but awards research grants to government and nongovernment organizations on a competitive basis. But it is reported that since no formal mechanism exists for consultation and interaction between NARC and NARDF, the risk of duplication of research has increased, and no mechanism exists to enable farmers to use NARDF results (Joshy 2012). Joshy lists several structural concerns in NARC that require attention, such as the bureaucratic mind-set in NARC that turns it into a business-as-usual bureaucracy; push and pull from political interference; no reward and punishment system; no motivation for young scientists, leading to brain drain; a lack of decisiveness in the NARC leadership; appointment of political faithfuls, not professionals to NARC; relevance of NARDF in the present research system; and NARC's structure being unfavorable for the participation of the private sector. Regarding scientist recruitment and promotion, the NARC recruitment committee, chaired by the executive director, has all the authority to recruit and promote staff (SAC 2012).

In Bangladesh, BARC is an autonomous organization under the MoA as an apex body of the NARS as well as the technical secretariat of the MoA with primary responsibility for research—unlike ICAR, which is responsible for research, education, and frontline extension (Kabir and Hussain 2012; SAC 2012). BARC operates with a governing body (highest) and an executive council. But unlike in India and Nepal, BARC has 12 constituent agricultural institutes that are under the control of four different ministries and that also differ in their status as being either autonomous or a government organization. The constituent autonomous institutes are managed by their own board chaired by their director general or minister-in-charge. As each NARS institute is part of a government department, operated by individual acts and separate service rules, there is no centralized provision for recruitment, no centralized plan for HRD, and different research review and planning processes. As a result the quality of the scientific staff among the institutes varies significantly. BARC fixes the criteria for selection of officers up to the chief scientific officer, and the individual agricultural research institutes (ARIs) handle the recruitment. BARC is responsible for the recruitment and promotion of chief scientific officers of autonomous ARIs under the MoA only. Since the promotion of scientists is based on civil service rules (that is, availability of vacancies), senior scientists with service of more than 15 to 18 years are stagnating (Kabir and Hussain 2012). The agricultural universities, NGOs, and private sector are not integrated with but are linked with the NARS in terms of research collaboration. The BARC Act of 2012 gave BARC more responsibility to ascertain agricultural research priorities, avoid duplication of research, disburse funds among the research institutes, and approve research projects. BARC's executive council reviews and recommends annual research programs and the budgets of the institutes. Unlike India's SAUs, eight agricultural universities in Bangladesh are under overall supervision of the Ministry of Education; however, the University Grants Commission is responsible for resource allocation including modest research costs. With budget constraints, the universities are participating in the grants provided by BARC through revenue and project budget and not any direct funding (Kabir and Hussain 2012). Like Nepal's NARDF and India's Agri Innovate India, Bangladesh established the nonprofit Krishi Gobeshona Foundation in 2007 under the Companies Act. This independent organization with an independent board of directors funds research under CGP by the NARS institutes, universities, other research institutes, NGOs, and the private sector (Kabir and Hussain 2012).

It is clear from the foregoing analysis that the governing bodies of the apex organizations should independently formulate and implement policy for an efficient research operation. Further, depending on the particular country's system, an efficient and effective functional autonomy is a necessity for the proper functioning of the NARS institutions. A science-centered administrative system should be introduced in the NARS instead of a civil-service-centered system. For better coordination and efficient management, all ARIs should be brought under a single ministry. Similarly, the NARS needs a centralized recruiting body for recruitment of scientists.

3.2 Institutional (Process) Issues

The institutional (process) issues of importance include priority setting, monitoring, and evaluation (PME); organization and management reforms; HRD; personnel policy; incentives and rewards; communication and publicity; partnership and linkages; and balancing competing agendas.

In the study countries, the PME mechanisms and their implementation differ, but they are generally subjective and weak. Such mechanisms are generally promoted and insisted upon during the implementation of externally aided projects; they are thus institutionalized in the system to ensure the optimum use of resources, establish higher returns to research investments, and create a favorable lobby for better funding from policymakers and support from the general public. In India many mechanisms have evolved over time, but in general they take the form of subjective assessments by experts rather than being more objective empirical analyses. However, in recent years India has practiced consultation with stakeholders besides using some supply-driven research prioritization exercises. With increased funding and a more complex research agenda addressing climate change, energy crises, price volatility, and so on, such subjective PME processes are inadequate. More objective processes are now being introduced in ICAR institutes through externally aided projects such as the National Agricultural Technology Project, National Agricultural Innovation Project, but several institutionalization problems persist, such as shortfalls in manpower and skills and an unsupportive mind-set (Mruthyunjaya 2012).

In Bangladesh, the PME process is subjective, and includes the different institutes and BARC conducting annual research review and planning workshops. Research review and planning workshops are mandatory and held annually at the institute level, but the process differs across institutes since they are autonomous. BARC organizes research program reviews separately to avoid duplications, ensure quality improvement, and ensure incorporation of national priorities. But recently Bangladesh conducted a priority-setting exercise for agricultural research as one of the tasks in developing its Vision 2030 document; the country formed 12 working groups and consulted widely with all stakeholders, finally holding a series of workshops at the regional and national levels. Analysts suggest that research priority setting should not be done ad hoc, but rather should be institutionalized with wider participation of stakeholders, particularly the technology users. Monitoring and evaluation of research programs must be done regularly with a view to quality improvement and justification of investment. For that to happen, research managers should be adequately trained with modern tools of impact assessment (Kabir and Hussain 2012; SAC 2012).

In Nepal as well, subjective processes were followed to prepare the Agricultural Perspective Plan (APP) (1995) and NARC Vision 2021. NARC's planning division guides the formulation of projects at NARC's institutes by sharing the recommendations of the Regional Agriculture Technical Working Group and the National Agricultural Technical Working Group along with guidelines from the MoAC, NARC, and the National Planning Commission. The performance evaluation of programs and institutes is reviewed at the MoA in the presence of the National Planning Commission and the Ministry of Finance under the chairmanship of the secretary of the MoA. Central-, regional-, and institutional-level monitoring and evaluation take place at NARC at the end of each fiscal year. Joshy (2012) reports that since at present no scientific mechanism for priority setting and resource allocation for AR4D exists, NARC allocates research resources in priority themes and commodities as identified in the APP and in NARC Vision 2021.

In our opinion, a review of NARS institution research programs by an external panel of experts every five years is essential to provide insights for further focus. PME mechanisms need to be institutionalized with adequate manpower and needed training. Impact assessments of the research programs need to be made mandatory.

3.3 Organization and Management Issues

Organization and management issues relate to administration and financial management problems. By the early 1990s, because of its large size, ICAR in India faced such problems (Mruthyunjaya and Ranjitha 1998; Mruthyunjaya and Pal 1999; Paroda and Mruthyunjaya 2000; Andy et al. 2001). To address the problems, ICAR tried to delegate powers at all levels. The solution was not adequate, as the delegated powers were not accompanied with the freedom and flexibility to use them or adequate training and capacity. Such issues are not reported much in Nepal and Bangladesh, which have smaller NARSs at present.

3.4 Human Resources Development

The capacity and quality of human resources is critical for advancing AR4D. As stated earlier, the situation is much wanting in Nepal and Bangladesh. Even in India, dwindling human resources quantity and quality, particularly in the SAUs, is a concern requiring priority attention. The challenges in HRD, as elaborated in the India country report (Mruthyunjaya 2012), include maintaining quality; inadequate state funding; depleted faculty; restrictions on recruitment; inadequate faculty development programs; a lack of competency of existing faculty in new and emerging areas; extensive inbreeding in faculty; a lack of modern teaching, research, and training infrastructure; opening new universities and colleges without additional staff and matching resources; a lack of integration of agricultural education with job creation; no educational planning; inadequate revision of course curricula; and a lack of teachers to teach revised curricula. The emphasis on education and training in resource allocation in the study countries is less when compared with research, which needs correction immediately. The Nepalese and Bangladesh governments have to substantially strengthen agricultural education and training facilities to provide required manpower to their NARSs for AR4D. The government of Nepal has announced the formation of the University of Agriculture and Forestry; that is a good step but it has yet to come to fruition (Joshy 2012). Nepal and Bangladesh can learn from the experiences of India's SAU system and design suitable undergraduate and postgraduate programs, including deputing students and scientists for doctoral or other advanced training in institutes of advanced studies, universities, and Consultative Group on International Agricultural Research (CGIAR) centers in the region and the globe with adequate and very liberal funding. Further, they may consider tie-up arrangements in the short run with India's National Academy of Agricultural Research Management (NAARM) for regular training programs for their researchers and research managers. In the long run, they may consider establishing NAARM-type research management and training institutes in their countries.

To overcome staff shortages in the NARS, and strengthen the merit, experience, and skills of the serving staff, one suggestion is to relax the retirement age to 65 years. Establishing an independent recruiting board for NARSs scientists centrally in Nepal and Bangladesh, as in India's ICAR, would maintain a uniform quality standard of the scientific staff. There needs to be a national agricultural research service cadre in each country as in India. A national agricultural scientist and emeritus scientist scheme should be introduced or strengthened to take advantage of a country's available national skills and expertise. Recruiting for senior management positions (directors and directors general) should be through national search committees and following practices as in CGIAR institutions.

3.5 Policies Regarding Scientific and other Personnel

The personnel policies governing recruitment, assessment, promotion, training, placement, and motivation of scientists play an important role in enhancing the efficiency of the research system. The study countries' personnel policies require a reassessment to create an enabling environment for doing the best science. In India, despite having a separate agricultural research service and Agricultural Scientists Recruitment Board, as well as a periodic revision of policies, problems persist. The system is less than perfect in that it doesn't identify merit; doesn't separate performers from nonperformers; allows restrictive government recruitment policies; allows keeping sanctioned positions vacant; opens new institutions without additional manpower and adequate infrastructure; lacks proper cadre planning and proper management and recruitment, including gender concerns; lacks freedom to quickly hire eligible scientific staff to meet emergent needs; restricts freedom of mobility across SAUs, the private sector, and other agencies; has no clear, smooth deputation policy for foreign training and travel; has a faulty selection procedure for top research managers; and lacks succession planning for research leaders. As can be seen in the country reports of Nepal and Bangladesh, some of the same issues are prevalent there, albeit at a lower intensity or in a latent form. For example, in Bangladesh, the incentive structure for scientists is weak; although it follows government rules, scientists are not entitled to government benefits like rest, recreational allowances, and so forth. In Nepal, scientists and other staff receive a salary and incentives similar to those in government civil service (SAC 2012). The retirement age for scientists is 59 years in Bangladesh, 62 in India, and 60 in Nepal. ICAR gives several awards annually or biannually to scientists and other staff for outstanding contributions as incentives and recognition of contributions. In Nepal, a service medal is given to those staff who have served the institution for 25 years or more. But there are not many such initiatives in Bangladesh. The problems need priority attention, as otherwise increased investments and intentions of better research productivity will remain only on paper.

3.6 Communications and Publicity

Agricultural researchers across South Asia are generally weak in communications and publicity skills. Because they do not adequately or properly project their contributions to stakeholders, they may not receive appreciation or full funding support. Basic communications and publicity skills have to be upgraded substantially in all the NARSs in addition to upgrading technical, monitoring, and impact assessment skills so that the systems can demonstrate that they are performing an essential service to society in contributing to meet its basic food and other needs. To address the issue, India's ICAR has established the Directorate of Knowledge Management in Agriculture and has taken several, mostly ICT-based, initiatives, although little results have been seen yet. In Nepal and Bangladesh, the issue needs urgent attention, as it is not adequately felt or covered at the moment in any explicit manner.

3.7 Partnership and Linkages

Working in partnership has become commonplace for organizations throughout the world as a means of addressing complex economic, environmental, social, and technological problems; capturing technology spillovers; and reducing research duplication. This includes multiorganizational partnerships such as networks, alliances, and consortia involving end users such as farmers, community groups, the private sector, traders, processors, and market agents in research or activities designed to foster innovation. Generally multistakeholder engagements happen at the planning level, but not many succeed at the implementation and impact level. Partnering with the private sector and NGOs has emerged as a necessary opportunity, and the necessity will persist in the future. The status of private-sector participation in AR4D is somewhat more pronounced in India because of favorable policies, as stated earlier. India's National Agricultural Innovation Project and Bangladesh's National Agricultural Technology Project (NATP) both have large components devoted to developing research consortia with civil society and the private sector. Nepal's NARDF similarly encourages diverse participation in research projects (Stads and Rahija 2012). The policies can be further improved to exploit emerging opportunities. ICAR has some structural entities for the purpose of functional interface and linkage, such as interdisciplinary panels; joint panels comprising ICAR and other scientific bodies like the Council of Scientific and Industrial Research, the Indian Council of Social Science Research, and the Indian Council of Medical Research; and eight regional committees. India is a member country of the South Asia Association for Regional Cooperation (SAARC), and formal activities are planned regularly to promote AR4D and other related activities. It has many international linkages including the Consultative Group centers, the Centre of Advanced Studies, and through memorandums of understanding and work plans, collaborative projects, visits, trainings, consultancies, organizing conferences and workshops, and exchange of materials. Although they have been helpful, much more would be possible if the functional interfaces, the SAARC and APAARI initiatives (regional), and the international linkages were faithfully implemented, closely monitored, and assessed for impact. The governments of Nepal and Bangladesh, depending on their need, have to strengthen such initiatives, including forming enabling policies as in India that are less at the moment to benefit from expanding opportunities for technology development and dissemination. Nepal's private sector in agriculture comprises households engaged in subsistence or semicommercial production (small and large), food processors, and manufacturers and traders. Although the government's major policy documents have stressed greater private-sector participation across all sectors of the economy, no specific measure has been pronounced to promote and support the private sector. The private-sector's involvement in AR4D is not yet encouraging due to the subsistence nature of agriculture in the country (Joshy 2012). It is suggested that BARC be given the responsibility of maintaining international research linkages like ICAR/DARE, and that international centers working in Bangladesh be encouraged to work in a collaborative and participatory mode with the NARS, rather than in isolation. This would ensure sustainability and capacity development of local institutions (Kabir and Hussain 2012). Collaborative research across South Asian countries on issues of subregional significance is still relatively limited, and efforts to build and enhance linkages need to be strengthened further to maximize synergistic opportunities (Stads and Rahija 2012). In areas such as biotechnology, ICT and remote sensing, policy research, and gender research, policy, training and bioinformatics, where India has good infrastructure and expertise, collaborative arrangements need to be pursued vigorously.

3.8 Balancing Competing Agendas

South Asian countries face an ever-expanding range of new, diverse, and competitive research and policy agendas. For instance, there is the need to develop capacity in frontier sciences while also supporting adaptive research for the traditional and subsistence sectors; the need to support but not compete with the private sector; the need to support competitiveness in global markets but not displace small-scale producers; the need to boost investment in genetic enhancement but not underinvest in conservation agriculture; the need to promote organic farming but not discontinue the use of chemicals; the need to enhance investment in technology generation but not downplay technology dissemination; the need to invest more in postharvest management but not decrease investment in increasing production; the need to invest more in production but not ignore food quality and safety; and the need to emphasize cultivation of staples while moving toward cultivation of high-value crops. Such diverse and competing agendas need to be addressed quickly and 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 only option to balance the agendas is cooperation and collaboration among all stakeholders within each country, across the region, and across the globe to share knowledge and resources. The conditions of success include willingness at the top level; greater capacity and commitment of the scientific community; better governance of scientific organizations; improved scientific infrastructure; national, regional, and international partnership; better funding and prudent use of funds; and enabling institutions and policies. Success stories with these features exist in different countries, but they have to be multiplied, shared, and institutionalized.

3.9 Funding for AR4D

We noted earlier that although overall growth in AR4D spending was positive during the 1996–2009 period, large differences existed across countries. ICAR is positioned relatively better in respect to funding support from the Indian government but the SAUs' position has worsened over the years. In Bangladesh and Nepal, support has been insufficient, volatile, and mostly dependent on the availability of funding through externally aided projects. Given the current low intensity ratios in the three countries, AR4D spending would need to triple or quadruple in the coming years to meet the emerging challenges (Stads and Rahija 2012). Governments remain by far the most important source of funding for public AR4D in the subregion. Donors and development banks still play a relatively important role in funding AR4D in Bangladesh and Nepal, compared with India, but overall agricultural R&D agencies in South Asia are less dependent on donor and development bank funding than their counterparts in other low- and lower-middle-income regions such as Sub-Saharan Africa or Central America (Stads and Rahija 2012).

All three countries have implemented competitive grant schemes for AR4D, often as part of externally aided projects. In India's ICAR, smaller-budget competitive grant schemes are implemented as part of the government budget, such as the National Fund for Basic, Strategic, and Frontier Application Research in Agriculture, besides as part of externally aided projects such as the National Agricultural Innovation Project (larger-sized projects). The budget outlay of the externally aided projects, however, on average has not exceeded 5% of the total spending on AR4D in India. Competitive funds are also provided by the Department of Science and Technology, the

Department of Biotechnology, and so on. New sources of funding are being successfully tried in ICAR like implementing revolving fund schemes; mobilizing resources through the sale of technologies, processes, and products; consultancy; contract research and training; partnership or joint ventures with the private sector; co-financing from other donors; support from a matching grant scheme of the Indian government; royalties on research products; and user fees for nonresearch products and services. ICAR has tried, unsuccessfully so far, to augment financial resources through prudent use and timely release by an online financial management system and simplified rules and procedures. Issues needing attention include distinction between plan and nonplan expenditures, standardizing unit costs of funding projects, systematic impact assessment studies, developing strong client organizations that can act as a lobby for AR4D, and mainstreaming the lessons learned in externally aided projects. ICAR supports the SAUs in research through projects and development grants that together account for nearly 50% of total spending in the SAUs.

In Bangladesh, the BARC-affiliated agencies receive funding primarily from government sources. The agricultural research investment trend in recent years has not been encouraging with very little difference in year-to-year budget allocations (Kabir and Hussain 2012). In the last few years only, a lump sum amount has been allocated for the implementation of the research programs of the ARIs and BARC over their revenue budget, which was mostly spent on staff salaries, other fixed costs, and routine research. The budget of a research institute needs to be fixed on the basis of its major research programs and performance as per national priority. Such major programs are supported for a fixed period after which sustainability of research or the management and use of the developed technology often becomes a problem (Kabir and Hussain 2012). There is a need for improvement in the NARS financial management. The World Bank–supported NATP also plays an important role in financing public AR4D. Founded as a component under NATP, the Krishi Gobishona Foundation funds AR4D projects with competitive grants. The higher-education agencies receive no direct government funding support for research purposes, but depend on the University Grants Commission. Donors like the U.S. Department of Agriculture and the European Commission have also supported large R&D projects at Bangladesh Agricultural University (Stads and Rahija 2012).

In Nepal, NARC received substantial funding through the World Bank–funded Agricultural Research and Extension Project, which ran from 1998 to 2002. When the project was concluded, the Nepalese government stepped up its support to NARC for a while (Stads and Rahija 2012). However, that government funding goes mainly toward salaries, compelling researchers to seek outside funding for their research activities. Evidence of falling productivity and production potential has always prompted a more critical stance on the part of managers of public funds, but there has been no official attempt to systematically compile, analyze, and document the research resources. Rather, an arbitrary ceiling is invented by the public fund managers for routine financial exercises for deciding public expenditure every year. Because of such ad hoc approaches, resource allocation in agricultural research is not only erratic but starved of funds, forcing scientists to sit idle in the laboratories (Joshy 2012). Because of the declining AR4D budget trend, staffing costs have overwhelmed (59%) all other expenditures. For example, in 2009–2010 operational costs, whose share was 34% in the past, declined to 22% of NARC's total budget indicating that, if not impossible, it was very difficult to carry out any new research project, thus pushing NARC into a status quo position. For NARC to be truly sustainable, a deep commitment is necessary from the government, and for AR4D in Nepal that is not yet the case (Joshy 2012). Joshy (2012), while listing the funding concerns in his country report, clearly states that as long as managers of public funds share the misconception that agricultural research support is a subsidy or a charity and not a wise investment for eradication of poverty, the full potential of AR4D as an engine of growth in the war on poverty cannot be achieved. AR4D in Nepal's NGOs is almost entirely funded by foreign donors. Founded in 2001, NARDF is a competitive grant scheme for AR4D. It was funded by foreign donors earlier but since 2009 has been funded solely by the government. NARDF funds 20 to 25 projects per year, and prioritizes collaborative proposals between government agencies, NGOs, and the private sector. Although the government in recent years has introduced monitoring of research studies supported by NARDF, there still is no mechanism enabling farmers to use the results of NARDF, as the extension agencies are reluctant to recommend them as their package of practices (Joshy 2012).

3.10 Technology Delivery System

As stated earlier, the public technology delivery system has not kept pace with South Asia's changing needs. In terms of resource allocation, several areas have not received priority: manpower support in both number and quality; training and skills upgrading particularly in the emerging subsectors of livestock, poultry, horticulture, fisheries, agricultural engineering, processing, and postharvest management; natural resources management issues, particularly adaptation to climate change; market, prices, and agribusiness; mobility and reach; and new extension methods and technologies, such as ICT. The public extension system is geared more toward crops than other topics that have become important in recent years. For instance, in India, only 5% of farmers access technological information on animal husbandry as compared with 40% for crops. The new technologies (biotechnology, nanotechnology, and others) present entirely different challenges in the technology development and delivery system with regard to quality, safety, IPR issues, and so on. The public-sector research system needs to explore new ways to use the private sector and NGOs in the transfer of technologies. Models exist that involve the private sector (private distribution of public technologies, private purchase of public research technologies and services) and NGOs (livelihood innovations, natural resources management technologies and best practices) that could be examined, customized, and used.

4. A Synthesis of Studies and Stakeholders' Views on AR4D Priority Setting, Financing, and Execution

In South Asia, investment in agricultural research has increased production of major agricultural commodities such as foodgrains, vegetables, fruits, milk, eggs, and fish severalfold. However, poverty and malnutrition continue to afflict more than one-fifth of the population.

All over the globe, including in South Asia, the public resources for agricultural research are becoming inadequate to meet AR4D's expanding objectives and complex agenda, although investment intensity rose from a meager 0.20% during the early 1960s to about 0.50% in 2008 in South Asia region. This, however, remains far below the average for all developing countries. Since most of the agricultural R&D is in the public domain, it is necessary that each research rupee or taka is spent efficiently. Thus there is a need to optimally allocate the available scarce resources. To address the complex issues facing agriculture in the region, there is a growing interest in structured, objective, and more transparent methods of priority setting involving various stakeholders representing different interests. This is crucial for the results and implementation of identified priorities (Manicad 1997).

Several formal, objective, or subjective approaches for agricultural research prioritization in the Asia-Pacific region have been attempted in the past, many of which were guided by APAARI. Several research prioritization studies were done in India, mostly 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). APAARI's efforts vis-à-vis countries in the Asia-Pacific are also significant in identifying research priorities using quantitative and consultative approaches initially and a quantitative approach lately (APAARI 1996, 2002, 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. The seven regional priority research areas were further broken down into more specific priority research themes within each research area. The commodity research priorities identified using the modified congruence method are cereals, livestock, cash crops, fruits, vegetables, plantation crops, oilseeds, pulses, fish, roots and tubers, and dry fruits (APAARI 2002).

The South Asia Association for Regional Cooperation comprises the governments of eight countries of South Asia, namely Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. In 2008 it developed the Vision 2020 document (SAARC 2008), which visualizes how the agricultural scenario will evolve in the near future and what policies and strategies will be appropriate to adjust to the emerging changes and harness their potential. Vision 2020 defines the priorities in agriculture including agricultural research for the different SAARC countries, and it states the way forward.

Regarding India, Jha and Kumar (2005), apart from identifying commodity and regional priorities, identified resource-orientation priorities. Their study revealed that nearly 35% of research resources were focused on germplasm, 26% on agrochemicals, and 21% on soil and water research. More than 55% were devoted to raising the productivity of natural resources. Material resources (agrochemicals, power, machinery) altogether claimed about one-third of the resources. The rest were spread over socioeconomic and other resources. Their assessment of the rationality of the current allocation with 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 the public good. Natural, human, and institutional resources are areas where private research has a very selective interest domain, driven entirely by product-specific interests.

In the *Report on Research Need Assessment and Agricultural Research Priorities for South and West Asia,* Mruthyunjaya, Pandey, and Jha (2004) conducted a research needs assessment and prioritization of AR4D in India. They identified research needs at the micro level in 28 pilot districts of the National Agricultural Technology Project executed in India during 1998-2005, a World Bank–supported research project, using strategic research and extension plans; performed research gap analysis by agroclimatic zone and by research needs versus current research efforts under NATP; prioritized the research gaps under nine themes, namely, genetic improvement, natural resources management, integrated pest management, integrated plant nutrient management, postharvest technology, water management, socioeconomic and policy research, animal management, and fishery management; and suggested strategies to bridge the prioritized research gaps through participatory involvement of research institutions, extension agencies, and development departments. Table 2 shows how research priorities in India have shifted over time.

Regarding Nepal, evidence of some effort toward the systematic prioritization in agriculture can be seen in the preparation in 1995 of the Agricultural Perspective Plan. In its preparation, various subject matter panels were formed with local consultants from different organizations related to agricultural development. The subject matter consultants consulted with various ministries and NARC and developed their subject matter reports. There was no stakeholders' meeting or workshop. Based on the subject matter reports, an international consultant prepared the APP for the government. The NARC Vision 2021 was prepared by NARC by holding extensive discussions within NARC and with various departments of the MoA. The local office of the UN's Food and Agriculture Organization also helped prepare the Vision document. The Nepal country report details the priorities reflected in the APP (1995) and in Vision 2020/25 (Joshy 2012).

In Bangladesh, BARC had done the priority setting in agricultural research, but recently, for the first time, in addition to different stakeholder views, the grass-roots-level perspective was taken into consideration. A hybrid approach was followed in priority setting involving people from the

Table 2—Shift in commodity/commodity group research priorities in agriculture and allied sectors in India as reflected in research studies (1995–2010)

Serial No.	Jha et. al (1995)	APAARI (2002)	Jha and Kumar (2005)	Mruthyunjaya and 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	

top as well as from the grass-roots level. The Bangladesh country report details the procedures and priorities identified (Kabir and Hussain 2012).

Mruthyunjaya and Kumar (2010) conducted a research prioritization for South Asia with respect to commodities and commodity groups using the modified congruence method. The study estimated the investment in R&D needed in South Asia to meet projected food demand to attain food and nutritional security for the people in 2015 and 2025 under two scenarios: (1) existing growth in food supply (2.14%) to meet national food security, and (2) target growth rate (4%) to meet the challenge of hunger and poverty in South Asia. The authors conducted the research prioritization to meet projected demand with an emphasis on the poor, because it was observed that priority scores differed according to income group. For example, for all income groups in the case of 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 on through responses from e-consultation and face-to-face meetings with stakeholders. The priorities are as follows:

4.1 Commodity Priorities

- Rice
- Milk

4.2 Commodity Group Priorities

- Cereals
- Horticulture

- Livestock
- Fishery
- Forestry

4.3 Overarching Priorities

- Natural resources management
- Socioeconomic and policy research
- Germplasm collection, conservation, and improvement
- Strengthening NARS institutions
- Strengthening basic and strategic research in the frontier areas of agricultural sciences

The results of the projected research investment requirement for South Asia revealed that at the current annual growth rate of the food supply, the resource funding (at current prices) has to be increased to US$3.461 billion from the 2010 level of US$2.246 billion by 2020. If a 4% growth rate is targeted to meet the challenge of hunger and poverty, then it has to be raised to US$4.590 billion from the 2010 level of $US2.246 billion by 2020.

4.4. Agricultural Research Prioritization: The Way Forward

How one approaches agricultural research prioritization is important since it may affect the uptake and impact of one's recommendations? As stated earlier, a bottom-up as well as top-down approach is preferred. In this context, the model referred to earlier (Mruthyunjaya et al. 2003) for convergence of macro-priorities with micro-priorities deserves attention. Research prioritization should be specific with respect 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 or one-level exercise. It is a time- and space-intensive, multilevel, and time-to-time 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-and-human-resources-intensive activity. Agricultural economists, by virtue of their education and experience, can lead the activity but cannot complete it without the involvement of other scientists and players in the system. The exercise may be undertaken less frequently at the higher level (say every five years) but may have to be done more often at lower levels of prioritization as changes are frequent and considerable there. The identification of generic priority areas may be adequate for donors to channel funding, but individual organizations of the regional NARSs, or at any other level, may need to fine-tune those generic areas for developing their own focused research agenda (APAARI 2002). Agricultural research prioritization exercises, particularly in developing countries, should follow some broad principles. Those include orientation of smallholders, pastoralists, tribal members, fishermen, and agricultural laborers; doing farming system research with an ecosystem perspective through needs-based diversification using value-chain approach, increasing the participation of farmers, NGOs, women, and youth; insisting on both public- and private-sector participation, blending traditional knowledge with modern technologies; stressing community-based resource management; extensive use of ICT; and enabling institutional, policy, and governance support.

Although identifying research priorities using different methods with a focus on target clients, target domains, and research approach remains important and should continue, the explicit use of such priorities in planning and execution of development programs is equally important. In general, we have found that the studies in research priorities are not explicitly referred to when identifying programs. Not doing so will dampen the interest of preparation of such exercises and may lead to subjectivity in the preparation of plans and programs—something to be avoided. Finally, we must strengthen research on methodological advances in research prioritization and impact assessment.

5. Analysis of the Potential of New Technologies

Several new technologies have the potential of scalable use. They include nanotechnologies, biotechnologies, advanced processing and packaging technologies, resource conservation technologies, ICT and remote sensing, biorisk management technologies, and mechanical technologies. This raises new issues in organizing NARSs related to economies of size, international collaboration, and public–private linkages (Byerlee and Alex 1998). By strengthening their national and international alliances with advanced research organizations, NARSs can tap the rapid advances in new technologies and knowledge and upgrade their capacity to use and regulate the new technologies, especially in IPR and biosafety. Since technology development is expensive, time consuming, and uncertain, we need to look at how technology transfer between nations can be encouraged and thus save costs and avoid duplication and also allow nations to learn from the successes and failures of others. We posit three situations: (1) find possibilities for nations to adopt the technological advancements of neighboring countries; (2) find possibilities where lessons from other countries can be modified as per the area- and region-specific needs of a nation; and (3) find possibilities that are unique to one's nation and develop a new series of learnings and technological innovations to address one's own priority needs. Also consider that some technologies are already commercialized (on the shelf) in some areas but need extension or replication in other similar areas; some are not commercialized but require translational research and technology management services to be used; and some are still in the basic and strategic stages. The estimated benefits of some new technologies in terms of yield improvement, reduced production costs, sustainable natural resource use, food production, and exports are provided in the publications of different countries (for example, for India, see ICAR 2010). The following are suggested general principles to govern the development and commercialization of new technologies:

- Do not exclude new technologies (such as genetically modified organisms and the use of cloned livestock and nanotechnology) a priori on ethical or moral grounds, although the views of people who take a contrary view deserve respect.
- Investment in research on new technologies is essential in light of the magnitude of food security challenges in the coming decades.
- Establish the human and environmental safety of any new technology before its deployment with open and transparent decision making.

- Make decisions about the acceptability of a new technology in the context of competing risks (rather than by simplistic versions of the precautionary principle); the potential costs of not using the technology must be taken into account.
- Since a new technology may alter the relationship between commercial interests and food producers, take this 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—claims that a single or particular new technology is a panacea are foolish.
- Given that a new technology has the potential to be very valuable for the poorest people in low-income countries, incorporate possible beneficiaries into decision making at all stages of the development process.

Similarly, one needs to plan funding and delivery mechanisms for the uptake of new technologies. In addition, countries should encourage public–private sector research, which provides private-sector firms with increased opportunities to develop new products (Laxmi, Janaki Krishna, and Reddy 2007). As indicated earlier in this section and also can be seen later in the section, the status of development and use of new technologies is better. However, the status of development and use of new technologies is at a modest level in the South Asian countries, particularly in Nepal (Joshy 2012) and Bangladesh (Kabir and Hussain 2012).

5.1 Nanotechnology

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. Nanotechnology has the potential to revolutionize the healthcare, textiles, materials, ICT, and energy sectors. A U.S. Department of Agriculture roadmap first addressed the application of nanotechnology to the agricultural and food industries in 2003. It is predicted that nanotechnology will transform the food industry, changing the way food is produced, processed, packaged, transported, and consumed (nanoforum.org, April 2006). The main countries in which significant investments are being made in this technology are the United States, Japan, the European Union, China, India, South Korea, Iran, and Thailand. A study by the Helmuth Kaiser Consultancy predicted that the nanofood market will surge from US$2.6 billion to US$20.4 billion by 2010. The Business Communications Company, a technical market research and industry analysis company, estimated that the market for nanotechnology was US$7.6 billion in 2003 and would be US$1 trillion in 2011. However, the full potential of nanotechnology in the agricultural and food industry has not been realized in any of the South Asian countries. Kalpana Sastry et al. (2010) assess the implications of current trends in nanotechnology for India's agrifood sector using published literature and patent data. They map the research themes in nanotechnology, and demonstrate clearly the multifaceted applications of nanotechnologies in 12 areas across the agricultural value chain for the Indian agrifood system. They note that biosynthetic pathways can be identified as a priority area for research investments in agrifood nanotechnology. Regarding safety, they suggest involving 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 nanotechnology researchers and policymakers to perform risk assessment before commercialization of nanotechnology products. As for Nepal, nanotechnology is new there, in spite of its multifaceted applications in agriculture and several other areas (Joshy 2012).

5.2 Biotechnology

Biotechnology offers improvements in several areas including agriculture, food and nutrition, animal husbandry, fisheries, biosecurity, medicine, and bioenergy. A compelling case for the intervention of biotechnology can be made: it can contribute to (1) increasing crop productivity and thus contributing 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) improving economic and social benefits and alleviating poverty. Biotechnological interventions have already made a global impact and offer scope for revolutionizing agricultural production and farmers' incomes in the coming years. They 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 incorporating foreign genes of interest into target crops and animals. India has seen several vivid outcomes of biotechnological efforts: Bt cotton; improved varieties of rice (Pusa Basmati-1 and Sambha Mashuri, tolerant to bacterial leaf blight, and Swarna-sub1 and Mashuri-sub1, with the ability to tolerate complete submergence in floodwater for up to two weeks); synthesis of vitamin A in rice endosperm; golden rice for biofortification of essential nutrients in a foodgrain; conversion of C3 rice plants to C4 plants; creation of immunity to rust diseases in wheat and bacterial leaf blight in rice; decoding of the pigeon pea genome; Vivek QPM9 maize; tomato genome sequencing; breeding to develop grape cultivars suitable for winemaking; black pepper cultivars rich in the aroma compound caryophyllene; development of processing tomatoes, potatoes for chip making, white onion with high soluble sugar, and papaya varieties for the table and papain production; in vitro propagation technologies in banana, potato, and citrus; and buffalo cloning. Singh (2012) summarizes the present and near future scope of biotechnological research and development in plants, animals, fishes, and microbes. According to Pray and Nagarajan (2012), in India biotechnological innovations went from zero in the 1990s to five genetically modified traits in hundreds of genetically modified (GM) cotton cultivars by 2008; pesticide registrations went from 104 in the period 1980–1989 to 228 during the period 2000–2010; and similar growth in innovations also occurred in agricultural machinery, veterinary medicine, and agricultural processing. The Swaminathan Task Force on Biotechnology (2004) prioritized target traits in crop plants, livestock, and fisheries. Currently, some 50 transgenic events in various crops expressing different traits have been awaiting commercialization since 2006 (Personal communication from Dr.Anand Kumar). They were developed in both the public and private sectors after long years of intellectual pursuit by scientists at an average expenditure of 6 crore rupees to 8 crore rupees on each and would ensure 30% to 40% more yield and 20% to 30% cost savings. Our preparedness in terms of the availability of state-of-the-art facilities to quickly undertake prescribed environmental and biosafety tests is grossly inadequate. This state of affairs not only demoralizes scientists but also ensures that society does not benefit from scientific breakthroughs. About half of the breakthroughs belong to public research institutions. The more important crops, such as rice, chickpea, mustard, groundnut, tomato, and sugarcane, that express important agronomic traits are being tested (Mruthyunjaya 2012). The benefits of such GM food crops will be groundbreaking and spectacular in enhancing crop productivity, thereby extending food and nutritional security to the teeming millions. But the moratorium on the release of Bt brinjal has affected the morale of the researchers involved in development and testing of these GM crops. The prevailing uncertainty is not conducive to the progress of GM technology, the application of which in agriculture is urgently needed by India. India does not have the luxury of rejecting new technologies for agricultural growth (Pental, 2012). Joshy (2012) reports that the recent row that has flared up in the media in Nepal over the multinational seed company Monsanto's plans to introduce its hybrid seeds in the country indicates our unpreparedness to quickly undertake prescribed environmental and biosafety tests.

5.3 Advanced Processing and Packaging Technologies

Several promising advances in this category are under research and development. They include bulk handling systems for fruits and vegetables (F&V), livestock, and 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 product processing; residue-free integrated pest management technology; and cool chambers on the principles of evaporative cooling (Singh 2012). Another development is value addition through dehydration of F&V, including freeze-drying, dried and processed F&V and spices, and fermented products. The opportunities in the fast-food business include development of new products like juices, chips, essential oils, and fruit wines; extruded products from millets; extractors for chilies, tomato, tamarind seeds, and pomegranate arils; and dried powders from beetroot, carrot, green chili, *sarson saag,* ginger, garlic, and onion. Packing materials like corrugated fiberboard boxes, perforated punnettes, cling film wraps, and sachets are being standardized for packaging of different fresh horticultural produce (India, DAC 2012). Nepal is seeing new products developed through value addition by various techniques, and this has brought tremendous opportunities to the fast-food and spice industries, which are growing rapidly (Joshy 2012).

5.4 Resource Conservation Technologies

Organic agriculture integrated with resource-conserving technologies can minimize the degradation of land and 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 produce more at low costs, improves soil health, promotes timely planting, ensures crop diversification, reduces environment pollution, and combats the adverse effects of climate change. Such technologies include laser land leveling; double-till, no-till in a rice–wheat system; turbo-seeding to avoid soil compaction; dual-purpose wheat technology for fodder and grain production; diversification and adoption of micro-irrigation technology in irrigated areas; and watershed management in arid areas (Haryana Kisan Ayog 2012).

5.5 ICT and Remote Sensing

The rapid growth of computer science has led to a number of ICT applications using integrated model–based systems with database system concepts. They include decision support systems, executive support systems, management support systems, and process-oriented information systems. Such systems should be used more heavily in different sectors such as water management, soil management, plant protection, market prices, and weather advisory systems. Similarly, space technology can play an immense role in agricultural research, such as 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. Future applications include precision agriculture, monitoring of climate change, risk management and enterprise insurance, spatial data modeling and mining, and small area estimation (Singh 2012).

ICT tools can be highly useful in agricultural extension. This vital service, being government run, is currently in not good shape across all countries in South Asia and is proving to be the weakest link in the transfer of modern technology and its deployment in farmers' fields. The reach of state government extension agencies is rather limited—extension workers generally do not manage to contact even half of all farmers. The rest are completely left out. ICT can increase the reach of 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 great benefits. Consider the United States, where young farmers are using YouTube for farm advisory purposes.

5.6 Biorisk Management

Despite inadequate resources, South Asia needs to focus on its integrated pest management (IPM) strategy with location-specific adaptation. More regional-level institutions taking the whole farming system as their clientele need to be put in place in different parts of India, innovating location-specific technologies including the chemical, biological, and cultural ingredients for minimizing pest and disease losses to commodities (Singh 2012). IPM practices have reduced overdependence on pesticides. The recent alignment of such IPM modules into Bureau of Indian Standards, -standardized Good Agricultural Practices has brought credible alignment with World Trade Organization–supported trading of agricultural commodities (India, DAC 2012). Breeding for resistance to the stem rust strain Ug99 is in progress. Presented with new biotic stress problems—such as three mealy bug species in various crops, *Spodoptera* damage in soybean and cotton, mites, thrips, and the root knot nematode in rice—research programs are being put in place to address those problems and provide mitigation to farmers (India, DAC 2012). The transboundary movement of pests (insects, mites, diseases, nematodes, and weed seeds) and animal diseases needs to be subject to laws and rules in all states, supported by the federal system. South Asia needs capacity development in human resources and infrastructure to pursue further research and monitoring in this area (India, DAC 2012).

5.7 Mechanical Technologies

The mechanization of agricultural operations can increase the efficiency of farm operations and help overcome seasonal labor shortages. Private manufacturers will play an important role in the commercialization of modern farm implements that can be adopted by resource-rich farmers. Public research should lead the way in supporting strategic research to support the manufacturing industry keeping in view the interests and specific needs of small and marginal farmers (for example, development of appropriate farm machines or facilitation of custom hiring system in rural areas). Gender-friendly devices also need to be developed (Singh 2012). Significant leading technologies under farm mechanization in the recent period include the precision seeder, manure spreader, root crop harvester, garlic planter, vegetable seedling planter, hydraulic platform for fruit harvesting, straw combine with integrated trailer, and tractor-mounted forage harvester.

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

6. A Strategic Plan for Enhancing AR4D in Terms of Improved Research Prioritization, Expanded Sources of Funding and Investment, and Innovative Delivery and Dissemination of AR4D

The underlying structure, organizational culture, managerial and financial norms and procedures, innovative and bold policy initiatives, political-economic factors, and program planning, monitoring, and evaluation culture and practices decide the policies and investments and pace and pattern of performance of every sector and segment of the economy, including AR4D. The strategic plan has to factor in this reality while extending the gains of technologies (including biotechnologies and other new technologies) and fresh gains from investing in basic and strategic research, both internal and imported. Further, the strategy has to move from knowledge generation to innovation and use by involving all stakeholders at all levels. It is important to recognize that the new knowledge, capacities, skills, research priorities, structures, processes, and funding mechanisms can contribute to improved livelihoods of the poor only when complemented with adequate and effective investment in providing agroservices combined with able governance and commitment mostly by the government, which is the dominant player in providing research services in South Asia. But private-sector involvement in a public–private partnership mode in each investment activity will be necessary, as can be seen from some success stories in India (Pray and Nagarajan 2012). The lessons learned from such success stories suggest that the dialogue on the public–private partnership role in agricultural R&D has to move beyond partnership since clear domains of comparative advantage (seeds, agrochemicals, 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 will become more and more important in balancing diverse and competing research agendas with the development and application of new, frontier technologies, as outlined earlier in the report.

6.1 Research Priorities

As a part of the GCARD 2 exercise, the research priorities identified during GCARD 1 for the study countries as well as for South Asia as a whole are reexamined using the methodology indicated in section 1 to address the changed context of increasing challenges of adaptation to climate change and global economic shocks and price volatility. Table 3 shows the resulting research priorities by type and country as well as for South Asia. The types of priorities include commodity, commodity groups, and resources management and other for South Asia derived out of country priorities.

For South Asia as whole, rice, maize, wheat, pulses, oilseeds, and milk are identified as priority commodities indicating their continued importance in the South Asian diet, and importance in ensuring food and nutritional security. Since significant changes are taking place in the South Asian diet, along with considerable improvement in per capita income, the priorities are also shifting toward high-value agriculture, including horticulture and livestock including poultry and fishery. To support high-value agriculture, particularly the growing livestock sector, increasing the fodder supply is emerging as a regional priority.

The region's natural resources are overstressed, and any further stress is feared to wipe out productive agriculture and livelihood security. Therefore, the most striking resource focus priority for the region is natural resources management, including adaptation to climate change, resources conservation, and efficient input use, particularly water. The next most important concern of the region is the value chain, particularly for high-value and perishable commodities that are fully integrated with the market. Benefiting from the growing market orientation in agriculture is itself a priority of the region. The other resources management priority is managing genetic resources to enhance productivity in a sustainable manner, including addressing biotic and abiotic stresses using new tools like biotechnology. Labor availability for agriculture is also emerging as a major concern in the study countries, and therefore farm mechanization is identified as an important regional priority. Another overarching regional priority is to benefit from high-value agriculture covering perishable commodities and from good marketing, processing, and postharvest management and value addition with an emphasis on food and biosafety safeguards. These research priorities truly reflect resources management and other concerns and opportunities in the region for accelerated, inclusive, and sustainable growth. Therefore, they should receive priority attention and increased, ongoing investment.

The priority profiles of the individual countries in the region indicate special features and needs. They suggest additional priorities beyond the ones identified for the whole of South Asia. For example, in the case of India, which is a large, dynamic country, supply chain management, rural energy management, and transboundary disease management are its other identified priorities.

For Nepal, a small and developing country, meat, poultry, large cardamom, ginger, small livestock, animal health, and nutrition are other key research priorities. For Bangladesh, the other key priorities include research on sugarcane, jute, egg, shrimp, prawn, forestry, biofortification, disaster management, and emerging pests and diseases.

With India being a large country with ecologies similar to its regional neighbors (West Bengal and eastern India represent the situation of Bangladesh; the states of Himachal Pradesh, Uttarakhand, and Jammu and Kashmir represent situations of Nepal), the unique priorities of the neighboring countries are equally relevant in India, particularly in those similar conditions and circumstances. In other words, India represents the region in many respects, indicating unlimited opportunities for shared development through regional cooperation and collaboration. Countries' political will to avail themselves of this opportunity should be strong and stable.

The uniqueness of the GCARD 2 study is that it has not only revised the GCARD 1 research priorities but also identified priorities with respect to the structure, processes, funding, and technology delivery systems of the study countries. This value addition to the research prioritization exercise is necessary because the expected impact of the implementation of the research priorities re-identified above depends heavily on the nature and friendliness of the enabling structural,

Table 3—Country research priorities: A synthesis

Type	India	Nepal	Bangladesh	South Asia
Commodity priorities	Rice, maize, wheat, milk, pulses, oilseeds	Rice, maize, wheat, small millets, oilseeds, legumes, jute, milk, meat	Rice, wheat, maize, pulses, oilseeds, sugar-cane, jute, milk, egg, shrimp, prawn	Rice, maize, wheat, pulses, oilseeds, milk
Commodity group priorities	Cereals, horticulture, livestock including poultry, fishery, high-value agriculture	Crops; horticulture and commercial crops (F&V, floriculture, large cardamom, ginger); livestock (milk and milk products, buffalo meat, poultry, small livestock like sheep and goats, feed and fodder, livestock health and nutrition); aquaculture and fisheries	Crops; horticulture (F&V, spices, potato); livestock; forage crops; fisheries	Cereals; horticulture; livestock; fodder crops; poultry; fisheries
Resource management and other priorities	NRM including adaptation to climate change, resource conservation; water use efficiency; value chain and market integration, GRM; biotechnology farm mechanization, processing, value addition; rural energy use and management; trans-boundary diseases	NRM including adaptation to climate change; biotechnology; farm mechanization and processing, postharvest management and food and biosafety	NRM including adaptation to climate change (land, soil, water), resource use efficiency; forestry; biotechnology and ICT, value chain and market integration; agricultural mechanization; postharvest management including food safety and biofortification; disaster management in agriculture; emerging pests and diseases	NRM (soil, water, biodiversity) including adaptation to climate change, resource conservation, efficient input use particularly water; value chain integrated with market, GRM; biotechnology, farm mechanization, processing and post-harvest management; food and bio-safety

NRM = natural resources management; GRM = genetic resources management; F&V = fruits and vegetables; ICT = information communications technology.

process-funding, and technology delivery ecosystem in each respective country. This was strongly expressed in the country dialogue meetings. Such priorities are provided in the following sections by country as well as for South Asia as a whole.

6.2 Structural and Institutional (Process) Priorities

Table 4 shows the structural and institutional priorities identified for the region, the most important of which is to de-bureaucratize the agricultural research systems and make them professional bodies (think tanks or brain trusts) with flexible rules and procedures with accountability to pursue creative science. They should have service rules with built-in incentives, have an independent recruitment body, and pursue favorable policies for promoting national (research–extension–farmer–market

Table 4—Structural and institutional priorities

Nepal	India	Bangladesh	South Asia
1. Recruit through an independent commission 2. Dissolve NARC's executive board 3. Ensure NARC's functional autonomy with no political interference 4. Evolve NARC as a NARS 5. Make the linkage between NARDF and technology delivery system mandatory; pursue collaborative projects; and institutionalize training 6. Mandate linkages with the private sector, NGOs, academic institutions, and other stakeholders 7. Make ARIs Deemed Universities 8. Establish technical advisory committees 9. Have professionals lead the NARC 10. Recruit the executive director of NARC openly using defined criteria	1. Find the political will to adequately fund AR4D and support the NARS 2. Cast ICAR as mainly a policymaking organization—a brain trust or think tank 3. Address women and youth issues and their involvement in research 4. Strengthen the consortium mode of conducting research 5. Promote greater autonomy in the NARS 6. Balance investments in research, education, and extension; strengthen basic, strategic, and socioeconomic and policy research; fund research on harsh ecosystems; fund research on rural nonfarm enterprises; strengthen public–private partnerships 7. Focus research; build centers of excellence; build more IARI-type institutes 8. Ensure that the university system deals directly with farmers to bridge the knowledge gap 9. Redefine the ultimate beneficiary of research to include farmers, farmer organizations, GOs and NGOs, processors, traders, and the private sector 10. Promote effective science communication and policy dialogue	1. Unify the service rules for the NARS institution scientists 2. Empower the BARC governance board to make all decisions related to NARS AR4D 3. Abolish the composition of schedule A and B ARIs, and have only one composition 4. Maintain a continuous HRD program at home and abroad 5. Build a strong PME system in the NARS management system 6. Give the ARI management board all required authority to implement its programs 7. Encourage scientists to retain their disciplinary positions and up to the highest scale; ensure adequate incentive package and accountability in the system 8. Transform the ARI regional stations into independent research stations with required authority 9. Strengthen research extension and private partnership 10. Have government sponsor the research endowment fund	1. Make structural and institutional changes in the NARSs to strengthen them as professional bodies, think tanks/brain trusts, and policymaking bodies; let the NARSs have their own rules, procedures, personnel policies, and service rules with inbuilt incentives and rewards and independent recruitment bodies; give NARSs functional autonomy; promote partnership with the private sector, NGOs, and civil society; fund basic and strategic, multidisciplinary, and multi-institutional research in the consortium mode, emphasizing research on the unfavorable ecosystem and women and youth in farming system perspective including rural nonfarm enterprise options; broaden the beneficiaries of AR4D 2. Develop political will; build centers of excellence; establish R–E–F–M private-sector linkage 3. Promote massive, liberal, national, and international HRD 4. Strengthen long-term planning, visioning, PME, and the communications system in the NARS

NARC = Nepal Agricultural Research Council; NARS = national agricultural research system; NARDF = National Agricultural Research and Development Fund; NGO = nongovernment organization; ARI = agricultural research institute; AR4D = agricultural research for development; ICAR = Indian Council of Agricultural Research; GO = government organization; BARC = Bangladesh Agricultural Research Council; HRD = human resources development; PME = priority setting, monitoring, and evaluation; R–E–F–M = research–extension–farmer–market.IARI=Indian Agricultural Research Institute

[R–E–F–M) and international partnerships with the private sector, NGOs, and civil society. Other priorities include strengthening AR4D institutions; conducting basic and strategic, socioeconomic and policy, and multidisciplinary research in a consortium mode; looking at things from a farming-system perspective; focusing on small farmers, women, and harsh ecosystems; conducting massive, liberal, national, and international HRD; long-term planning and visioning; and developing a strong PME system to ensure scientific rigor and clear evidence of systemwide impact.

As can be seen, the priorities under this heading echo the earlier described priorities but emphasize areas of concern especially significant to the particular country. For example, for India, which has a large, highly evolved NARS, the following priorities are emphasized: mobilizing a strong political will; greater autonomy to ICAR; emphasizing policymaking; having ICAR and the NARS act as a brain trust organization instead of indulging in micromanagement of constituent institutions; rationalization, consolidation, and integration of institutions with clear mandates; focused and balanced investment in research, education, and extension; building centers of excellence like IARI rather than thinly spreading resources; strengthening basic, strategic, socioeconomic, and policy research, including research on the rural nonfarm sector; broadening the composition of beneficiaries to include farmers, processers, traders, and transporters; and promoting effective science and policy communication. In short, India needs to focus on institutional reforms that enhance autonomy, activity focus, rigor, evidence of impact, the right workforce, and effective communication and policy dialogue.

Bangladesh will benefit from unified service rules for scientists of the NARS institutions; empowerment of BARC's governing body to make all decisions related to the NARS; replacing the composition of schedule A and B institutes with a single composition; having scientists retain their disciplinary positions up to the highest scale; transforming the ARI's regional stations into independent research stations with necessary authority; and having a government-sponsored research endowment fund. In short, Bangladesh needs to focus on institutional reforms with more autonomy, flexibility, and unified governance of all ARIs.

Nepal's structural and institutional priorities are recruitment through an independent commission; abolition of NARC's executive body; evolving NARC as a NARS; functional autonomy; no political interference; linkage of NARDF with a technology delivery system; mandatory public–private sector linkage; professionalization of NARC; making ARIs made Deemed to be Universities; investing heavily and liberally in HRD; establishing technical advisory committees; having NARC led by professionals; and recruiting the executive director of NARC through defined criteria. In short, Nepal needs to focus on increased and assured funding, institutional reforms, and capacity building.

6.3 Funding Priorities

Table 5 shows the funding priorities for South Asia as well as the individual study countries. The regional priorities include enhanced investment in AR4D by at least three to four times the present level; more core funding from government; exploring multiple sources of funding like competitive grant schemes, revolving funds, matching grants, co-financing; international collaboration; attractive salary and service conditions to attract and retain talent; integration of donor-funded research with development; following best funding practices like adequate funding and timely release; funding for HRD; technology dissemination and policy advocacy; and clear-cut IPR policy and cost- and IP-sharing rules to promote public–private partnership and commercialization of technologies.

Those priorities apply to all the study countries, but each country also has some unique funding priorities. India would do well to focus on timely funding, transparency in funding, involving stakeholders in funding decisions, and establishing equity in funding to all the research providers. Nepal would do well to prioritize its research and funding to a needs-based agenda; maintain a firm funding commitment by the political system; fund HRD; use special incentives to attract and retain youth in AR4D; make research an attractive profession with incentive, salary, and service conditions; integrate mega donor projects with development; and ensure that there is funding to cover the risk of crop failures.

Bangladesh's main funding priorities are to enhance core funding from the government; explore new funding mechanisms like competitive grant schemes and revolving funds; co-finance research programs in collaboration with developed countries; secure donor funding for demand-driven research of national interest; and implement a clear-cut IPR policy to attract private funding.

6.4 Technology Delivery Priorities

Table 6 shows the technology delivery priorities for South Asia and the individual study countries. The overarching priorities under this heading include to strengthen science and technology in agriculture; promote innovations for yield improvement by addressing the challenges of climate change, input use efficiency, and price volatility; involve scientists, the private sector, NGOs, and cooperatives in technology dissemination; strengthen research documentation; make extensive and innovative use of IT in technology dissemination and promotion and access to inputs and services; strengthen the technology communication and marketing system; build in a provision for technology communication dissemination in each project; implement an open-door policy for technology import from the globe; strengthen the input delivery system with supportive institutions and policies; recognize and involve innovative and champion farmers and empower women through training in agricultural technology; and have an effective policy dialogue with the political system, policymakers, activists, and the general public to dispel myths about threats from new technologies and policy and institutional innovations.

Some unique priorities are indicated by the country profiles. For instance, Nepal should get scientists, the private sector, NGOs, and cooperatives involved in technology dissemination; strengthen its technology marketing system; make extensive use of ICT; and bridge the knowledge and information gap between researchers and end users.

India would do well to prioritize the development and dissemination of technology for improving yields through hybrid, pest-resistant crops; technology commercialization; the promotion of producer companies; and the dovetailing of the recommendations of research and extension agencies in technology dissemination.

Bangladesh's technology delivery priorities include price incentives for technology adoption; strengthening research on adaptation to climate change in agriculture; involvement of the private sector and progressive farmers in technology transfer; participatory research with farmers; empowerment of women; rainwater collection and efficient use; ensuring technological support for lactating cow, calf rearing, and beef fattening; pulling more support from the government for the brood stock management and distribution system; improving the availability of quality seeds, saplings, Artificial Insemination service, and veterinary treatment and other inputs and services at the grass-roots level.

Table 5—Funding priorities

Nepal	India	Bangladesh	South Asia
1. Gear priority setting and funding to a needs-based research agenda 2. Raise investment in AR4D from 0.39% to 2% of AgGDP 3. Strengthen the NARS with a firm political commitment 4. Strengthen HRD and retain talent and motivate women and youth in AR4D 5. Create pressure groups and mobilize people and stakeholders to plead for more resources for AR4D 6. Attract corporate funding to AR4D 7. Improve salary, service rules, and incentives to attract and retain youth in AR4D 8. Make research an attractive profession versus other professions by creating a suitable work environment and providing incentives 9. Mega donor projects should aim at integrating research with development 10. Budget enough to cover the risk of crop failure	1. Provide timely funding 2. Provide transparency in funding 3. Enhance funding 4. Provide funding for technology dissemination 5. Provide funding for HRD 6. Create long-term plan for AR4D 7. Ensure that funding criteria are broad-based and balanced to cover all aspects of AR4D 8. Provide funding for advocacy of research results 9. Involve stakeholders in funding decisions 10. Extend equity in funding to all potential research providers	1. Enhance core funding by government with accountability 2. Fund multidisciplinary research through competitive grant schemes 3. Encourage partnership in research funding with clear-cut cost-sharing mechanisms 4. Explore new funding mechanisms like revolving funds and co-financing 5. Provide adequate funding of at least 1% of AgGDP 6. Provide adequate funding for HRD 7. Establish joint research programs with developed countries through co-financing 8. Put in place flexible rules and procedures for research expenditure (local as well as foreign funded) 9. Seek donor funding for demand-driven research of national interest 10. Create a clear-cut IPR policy to attract private-sector funding	1. Enhance funding of AR4D by three to four times—at least 1% of AgGDP in the short run, 2%–3% in the medium and long run 2. Strengthen NARS with more core funding from government 3. Explore multiple/innovative sources of funding—competitive grant scheme, revolving fund, matching fund, co-financing, international collaboration 4. Use attractive salary and service conditions to attract and retain youth and talent in AR4D 5. Pursue donor projects to integrate research with development 6. Employ best funding practices like adequate funding, timely funding, funding for HRD, technology dissemination and advocacy of research results, equity in funding, flexible rules and procedures, clear-cut IPR policy and cost and IP-sharing rules to attract funding from private sector

AR4D = agricultural research for development; AgGDP = agricultural gross domestic product; NARS = national agricultural research system; HRD = human resources development; IPR = intellectual property rights; IP = intellectual property.

Table 6—Technology delivery priorities

Nepal	India	Bangladesh	South Asia
1. Promote private sector, NGOs, cooperatives, agrovets, and other service providers in technology dissemination	1. Pursue technology breakthroughs for yield improvement	1. Ensure fair prices to adopt storage technologies of all agricultural products	1. Strengthen science and technology in agriculture; promote innovations for yield improvement, adaptation to climate change, resource use efficiency, price volatility
2. Involve scientists more in technology dissemination	2. Promote technology commercialization	2. Strengthen research to mitigate the impact of climate change; dialogue effectively with the political system, policymakers, activists, and the general public to dispel myths about the benefits of new technologies, policies, and institutional innovations	2. Involve scientists, the private sector, NGOs, cooperatives, agrovets, and other service providers in technology dissemination
3. Documentation and extensive use of IT in technology delivery systems	3. Recognize innovative farmers and promote innovations	3. Involve the private sector and progressive farmers in technology transfer	3. Document research results and make extensive and innovative use of IT in technology dissemination and promotion of and access to inputs and services
4. Strengthen the technology marketing system	4. Promote technology extension through partnerships	4. Manage a coordinated research program through the participation of farmers and extension and research personnel	4. Strengthen the technology communication and marketing system in the NARSs
5. Use ICT extensively for promotion of and access to inputs and outputs	5. Have a stable policy for adopting technology by dispelling myths about the benefits of new technologies and other policy and institutional innovations	5. Ensure technological support for lactating cow, calf rearing, and beef fattening	5. Build a provision into each research project for technology communication and technology dissemination
6. Build a provision into projects for communication and technology dissemination	6. Institute an open-door policy for the import of foreign technology	6. Empower women through training on agriculture technology	6. Follow an open-door policy for accessing technology from the globe
7. Use NARS communications strength for technology dissemination	7. Promote producer companies	7. Expand government's role in brood stock management and distribution system	7. Strengthen the input and service delivery system with supportive institutions and policies to harness the full potential of technology
8. Follow a policy of accessing technology from the globe	8. Promote role players in upstream research and downstream work in extension	8. Ensure veterinary treatment and AI service at the grass-roots level	8. Recognize and involve innovative farmers and empower women through training in agricultural technology
9. Bridge the knowledge and information gap between researchers and end users through effective delivery and supply of inputs and services	9. Dovetail recommendations of research and extension agencies in technology dissemination	9. Evolve technologies to harvest rainwater and use surface water efficiently	9. Dialogue effectively with the political system, policymakers, activists, and the general public to dispel myths about benefits of new technologies and policy and institutional innovations
10. Dialogue effectively with the political system, policymakers, activists, and the general public to dispel myths about the benefits of new technologies and other policy and institutional innovations	10. Promote innovations in developing high-yield and pest resistant seeds	10. Ensure the availability of quality seed, saplings, and other inputs at the grass-roots level	

NGO = nongovernmental organization; IT = information technology; ICT = information and communications technology; NARS = national agricultural research system, AI=Artificial Insemination.

7. Summing Up

The priorities presented in Tables 3 to 6 relating to the study countries and South Asia as a whole are arranged in terms of their importance under selected types defined already. But for the strategic plan, we wish to identify the top 10 priorities irrespective of type for future AR4D in South Asia as a whole. The strategic plan underscores the critical need for greater regional research alliances and cooperation for significant gains. This is especially important as the spillover from yield-improvement technologies in developed countries is significantly decreasing under the new IPR regime; in addition developed countries have shifted their research focus toward value and quality aspects rather than yield improvement, creating a kind of technology orphan condition in developing countries. The strategic plan identifies the following top 10 priorities for future AR4D in the region:

1. South Asia has the highest concentration of the world's hungry and poor, more than Sub-Saharan Africa, and agricultural research has significantly contributed to the reduction of hunger and poverty in the region, but increased and stable investment in AR4D is not forthcoming from either the countries of the region (except India to some extent) or donors. Therefore, we recommend tripling or quadrupling AR4D spending in the coming years from the current level. That amounts to at least 1% of agricultural gross domestic product (GDP) in the short run and 2% to 3% in the medium and long run. This will require greater political will and a strong public lobby for the farming, scientific, and other communities. It will also require exploring innovative funding and fund-use mechanisms, linking donor funding to national development plans, better use of financial and procurement management practices, and more.
2. Intensify agricultural research by building consortia and partnerships with innovative incentives and involving all knowledge providers, including the private sector. Research should emphasize both staple crops in marginal ecologies, where the interest of the private sector is minimal so far, and higher-value products (horticulture, livestock, poultry, fish) with active partnership with the private sector, which is often a leading player.
3. Place a higher priority on research on (a) natural resources management, including adaptation to climate change, conservation of resources, and efficient input use, particularly with respect to soil and water, and (b) genetic resources management to sustainably raise yield ceilings, enhance biotic and abiotic stress resistance, and improve food quality and nutritional content.

4. Ensure the functional autonomy of the NARSs through de-bureaucratization and professionalize the NARSs as policymaking bodies and think tanks or brain trusts with science-friendly, flexible financial and administrative rules and procedures, competitive service conditions, merit and performance incentives, and structures to contribute to excellence in science for development.
5. Strengthen HRD nationally, regionally, and internationally with liberal funding and progressive training policies.
6. Strengthen agricultural education systems to continuously supply quality human capital to the agricultural sector and agricultural research system.
7. Strengthen technology delivery systems and agro-advisory services to increase the linkages, synergy, and convergence among scientists, extension workers, farmers (including women and farm innovators), farmer organizations, development agencies, the private sector, and nongovernmental organizations (NGOs) using modern technologies like ICT and innovative institutions like the *krishi vigyan kendras* and agricultural technology management agencies.
8. Strengthen soft skills like research policy; long-term planning; visioning and policy priority setting, monitoring, and evaluation; IPR and technology commercialization; agribusiness planning and development; documentation; and communications and publicity to contribute to better implementation of programs, systemwide impact, and the increased efficiency, credibility, and visibility of the NARSs.
9. Strengthen research on the value chain, engaging the private sector and all other potential players, and on market integration with a focus on an efficient and dependable inputs and services delivery system.
10. Strengthen agricultural engineering research on inputs and services covering primary processing, value addition, farm and rural storage, grading, rural energy use, small farmer mechanization, and precision farming to improve efficiency, add value, remove drudgery, and overcome increasing labor scarcity.

As can be seen, increased funding support tops the region's priority list, as it is critical to fully fund the NARSs to pursue AR4D. The next two priorities stress the role of commodity and resources management in increasing the supply of diversified commodities (to improve the food and nutritional security of the increasing population and boost per capita income) while preserving the integrity of the ecosystem. The next five priorities (50% of the priorities) relate to strengthening the enabling systems and bringing skills up to par with the best in the world to overcome the institutional deficiencies of the NARSs to support excellence in AR4D—without which increased funding and commodity- and resources-focused research may not reduce poverty and hunger and may even give the wrong signal to future resource flows. These priorities include good governance; a strong HRD and agricultural education system; partnership internally, regionally, and globally;

an effective technology delivery system; and improved soft skills to enhance the technology impact, efficiency, credibility, and visibility of the NARSs. The last two priorities relate to strengthening the value chain and market integration with agricultural engineering inputs including rural energy and small farmer mechanization to make agriculture rewarding and exciting.

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