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THE WORLD BANK OPERATIONS EVALUATION DEPARTMENT

# The CGIAR at 31:An Independent Meta-Evaluation of the Consultative Group on International Agricultural Research

## CGIAR Effectiveness — A NARS Perspective from India

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***ENHANCING DEVELOPMENT EFFECTIVENESS THROUGH EXCELLENCE AND INDEPENDENCE IN EVALUATION***

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## Abbreviations and Acronyms

| | |
|---|---|
| ADB | Asian Development Bank |
| AICRP | All-India Coordinated Research Project |
| CGIAR | Consultative Group on International Agriculture Research |
| CMDT | Change Design and Management Team |
| DARE | Department of Agricultural Research and Education |
| FAO | Food and Agriculture Organization |
| GCP | Global Challenge Program |
| GNPT | groundnut production technology |
| HYV | high-yielding variety program |
| IARC | international agricultural research center |
| ICAR | Indian Council of Agricultural Research |
| ICRISAT | International Crop Research Institute for Semi-Arid Tropics |
| IDM | integrated disease management |
| IFPRI | International Food Policy Research Institute |
| IPG | international public good |
| IRR | internal rate of return |
| IRRI | International Rice Research Institute |
| IRS | internationally recruited staff |
| KVK | Krishi Vigyan Kendra |
| MIS | management information system |
| MV | modern variety |
| NAARM | National Academy of Agricultural Research Management |
| NARP | National Agricultural Research Project |
| NARS | National Agricultural Research System |
| NRC | national research center |
| QPM | quality protein maize |
| RRO | regional research organization |
| R-W | rice-wheat |
| SAARC | South Asian Association for Regional Co-operation |
| SAREC | Swedish Agency for Research Co-operation among Developing Countries |
| CABI | Commonwealth Agricultural Bureaus International |
| SAT | semi-arid tropics |
| SAUs | state agricultural universities |
| SC | Science Council |
| SWOT | strengths, weaknesses, opportunities, and threats |
| TAC | Technical Advisory Committee |
| TNAU | Tamil Nadu Agricultural University |
| UNDP | United Nations Development Program |
| VL | village-level studies |

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# Contents

## Figures



## Tables

# Preface

This is one of two country working papers by independent scholars prepared as part of the meta-evaluation of the Consultative Group on International Agricultural Research (CGIAR) conducted by the Operations Evaluation Department (OED) of the World Bank. The report, entitled *The CGIAR at 31: An Independent Meta-Evaluation of the Consultative Group on International Agricultural Research*, is available on OED's external Web site: http://www.worldbank.org/oed/gppp/. The country working papers are: "Brazil Country Paper for the CGIAR Meta-Evaluation" by Jamil Macedo, Marcio C.M. Porto, Elisio Contini, and Antonio F.D. Avila and "CGIAR Effectiveness — A NARS Perspective from India" by Dr. J.C. Katyal and Dr. Mruthyunjaya.

The report on the CGIAR is part of a two-phase independent review by OED of the World Bank's involvement in global programs. The first phase has been published: *The World Bank's Approach to Global Programs: An Independent Evaluation, Phase 1 Report* (OED, Washington, D.C., 2002). The second phase, due in fiscal 2004, involves case studies of 26 programs, of which the CGIAR is one. The inclusion of the CGIAR evaluation in the OED review of the Bank's global programs was requested by the Development Grant Facility (DGF) and Bank Management in June 2001, and endorsed by OED's global program advisory committee.

While the focus of the meta-evaluation is on the Bank and the strategic role it has played and ideally will continue to play in the future in ensuring the CGIAR's development effectiveness, five thematic working papers and four country case studies focus on the different components of CGIAR activities that determine impact. In addition to informing a broader understanding of the policy and technical context of CGIAR implementation, the papers provide a tool for assessing the performance and impact of the whole CGIAR partnership; this, in turn, provides a critical context for gauging the impact and value added of the Bank's participation in the program, the primary objective of the CGIAR meta-evaluation.

The four country case studies — on Brazil, India, Colombia, and Kenya — provide developing country perspectives on the CGIAR. The Brazil and India reports are being issued as country working papers. Two country background papers — C. Ndiritu, "CGIAR-NARS Partnership: The Case of Kenya" and L. Romano, "Colombia Country Paper for the CGIAR Meta-Evaluation" — are available on request. The complete list of working and background papers and peer reviewers for the working papers is provided in Annex 3.

The CGIAR was the first program providing global public goods to receive grants from the Bank's net income. Although the program has an impressive tradition of self-assessments, System-level evaluations have been few and far between. An exception, the Third System Review (TSR), was carried out in 1998, 17 years after the previous System-level review. OED determined that a meta-evaluation would most effectively assess CGIAR performance and inform OED's overall review of the Bank's involvement in global programs. In brief, the objectives of the meta-evaluation were three-fold:

- Evaluate implementation of recommendations in the 1998 TSR review
- Identify issues confronting the CGIAR from a forward-looking perspective
- Draw lessons for overall Bank strategy on global public policies and programs

The meta-evaluation report is in three volumes. *The Overview Report (Volume 1)* addresses strategic questions regarding the organization, financing, and management of the CGIAR as these have affected research choices, science quality, and the Bank's relationship to the CGIAR. *The Technical Report (Volume 2)* explores the nature, scope, and quality of the System's scientific work, assesses the scope and results of the reviews, and analyzes the governance, finance, and management in the CGIAR. *The Annexes (Volume 3)* provide supporting materials and are available on request.

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# 1. NARS in India

1.1 Population growth rates in the developing world have been declining in recent years, and this is expected to continue (projected growth rates for the period 1995-2015 are 1.4 percent per year). However, the absolute number of people — and especially poor people — will continue to rise. Urbanization is expected to increase rapidly. It is estimated that more than half the population will live in urban areas by 2025. Even with that shift, poverty will remain primarily a rural phenomenon for the next 25 years. In 2020, South Asia will have about 80 percent of the world's undernourished children.

1.2 Agriculture is the backbone of Indian economy and will remain central to socio-economic development of India even in future. According to Asian Development Bank, agricultural growth is a prerequisite for economic development in general and rural development in particular. Indian agriculture, supported by Green Revolution technologies, is one of the most striking success stories of the post-independence era. It ushered in an era of food self-sufficiency and rural prosperity. The role of technological breakthroughs in this success is significant. Recent research by IFPRI (Fan and Hazell, 2000) found that expenditure on R&D and rural roads in India has had the largest impacts on both rural poverty reduction and agricultural productivity growth.

1.3 The agricultural revolution with application of modern technology started in India with the launching of High-Yielding Variety (HYV) program by the government. The program was introduced in 1966 when India's food production was low in relation to need. In 1966, the maximum amount of food was imported into this country, over 10 million tons, from the United States under its PL 480 Program, as well as Canada and the Oceanic countries. The rationale behind HYV program was the success associated with hybrid maize in 1961 when four double cross hybrids were released under a program jointly organized by the Indian Council of Agricultural Research (ICAR) and the Rockefeller Foundation. The introduction of first hybrid sorghum was in 1963. In 1964, India had identified two high-yielding wheat varieties — Lerma Rojo and Sonara. Next came the Punjab Agricultural University (PAU) hybrid on millet. Finally, dwarf varieties of rice like Taichung Native -I and IR-8 were introduced from Taiwan through IRRI. The potential yields of these varieties were two to three times higher.

1.4 In 1965, after verifying the position and their superiority on farmer's field, India made a historic decision to convert about 30 million hectares to these varieties. Swaminathan, a renowned Indian agricultural scientist, considers rice, wheat, maize, sorghum, and millet the five pillars of modern India's agricultural advance. The three themes in tandem that gave Indian agriculture its buoyancy over the past few decades include harnessing science and technology, strong policy and political commitment at both national and international levels (which moved bureaucracies, people, and resources), and investment mainly in irrigation, fertilizers, and agricultural research. The National Agricultural Research System (NARS) was at the forefront to guide technological breakthroughs.

1.5 Notwithstanding remarkable achievements on the food and agriculture front, several weaknesses persist in the Indian NARS, in addition to future challenges that are daunting and complicated. In this context, a review of NARS with respect to its structure, challenges, and needed orientation to remain effective and relevant assumes significance (Mruthyunjaya and Ranjitha, 1998).

# 2. Trends in Investment in Agricultural Research

## Size and Structure of NARS

2.1 India has one of the largest, most complex agricultural research systems in the world (Figure 1). ICAR, the national public sector agricultural research body, coordinates, directs, and promotes agricultural research and education for the whole country. It is funded mainly through lump-sum grants from the government and the proceeds of a levy on certain export commodities. Similarly, State Agricultural Universities (SAUs) are bodies for coordinating, directing, and promoting agricultural research and education at the state level.

2.2 Since independence, the National Agricultural Research System (NARS) has grown from a few central institutes, regional centers, commodity boards, and agricultural colleges addressing regional problems. The NARS, led by the ICAR, now has 4 multidisciplinary national institutes (universities), 45 central research institutes, 30 national research centers (NRCs), 4 bureaus, 10 project directorates, 84 All-India Coordinated Research Projects (AICRPs)/Networks, and 16 other projects/programs in the public sector. In addition, there are 28 State Agricultural Universities (SAUs) and one Central Agricultural University.

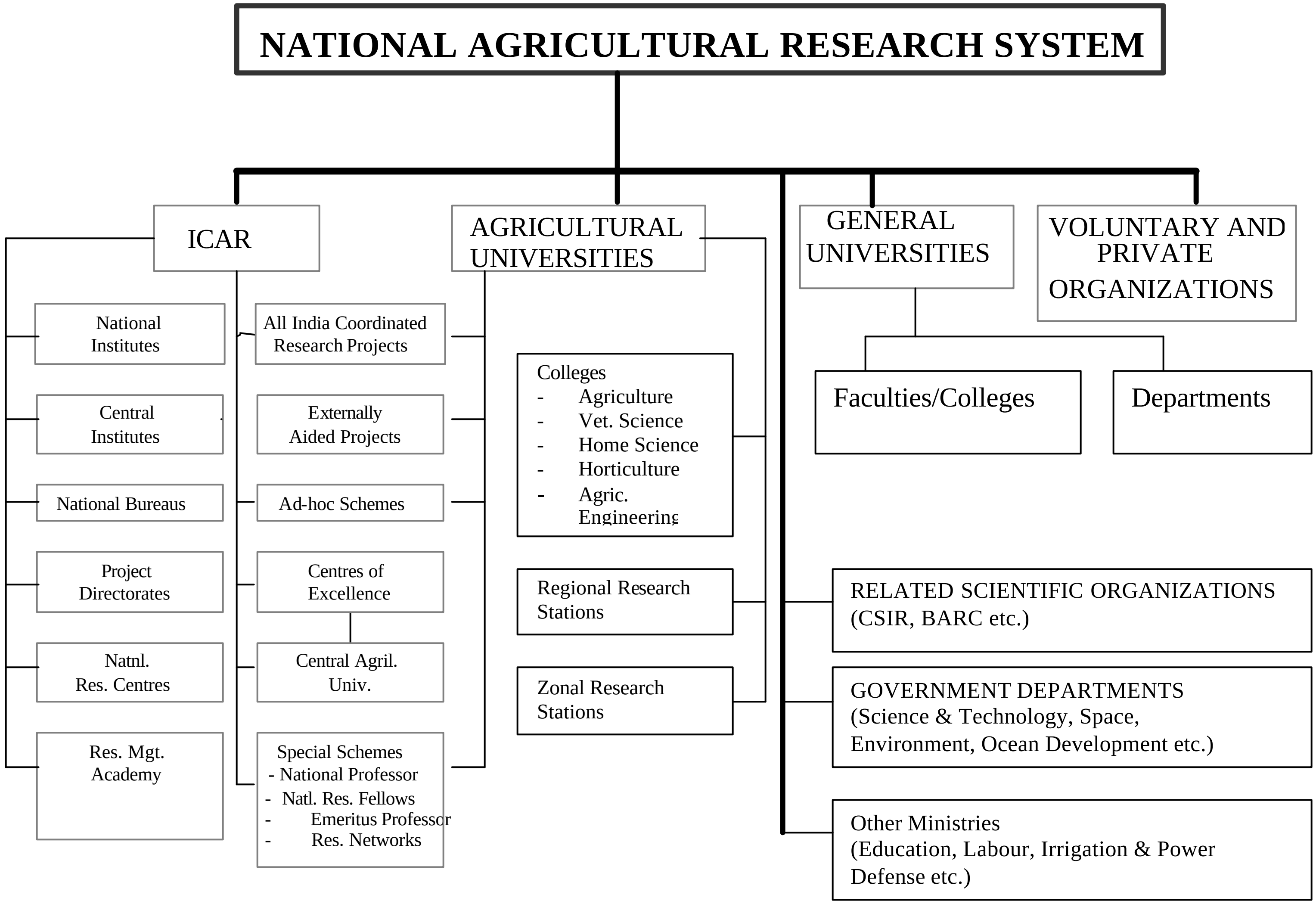
2.3 The AICRPs are the main links between ICAR and SAUs. The total number of centers involved in the AICRPs is about 1,300, with about 900 being agricultural university-based, 200 ICAR institute-based, and 200 based elsewhere. The National Academy of Agricultural Research Management (NAARM) is yet another unique institution under ICAR to impart training in agricultural research management. In addition, general universities (about 23 are involved in agricultural research), scientific organizations (like Council of Scientific and Industrial Research, Bhabha Atomic Research Centre), other government departments (like Department of Science and Technology, Department of Biotechnology), private and voluntary organizations (more than 35), and Scientific Societies (more than 105), are also involved in agricultural research and form part of the NARS (Ranjitha, 1996).

## Funding Sources and Trends

2.4 Agricultural research spending averaged Rs. 5000 million (about US$150 million) per annum during 1989-1992 at 1996 prices. The central government provides about 60 percent of all funds for agricultural research, state government about 20 percent, and private companies about 12 percent; foreign donors provide the rest (Ranjitha, 1996). ICAR currently receives most of its funds from the national budget, in part financed by external loans and grants. This is supplemented by its own earnings and allocations from an Agricultural Produce Cess Fund, which is used as competitive grants to finance individual scientists and organizations.

2.5 International support — particularly from the World Bank for agricultural research and extension — has been important in helping to create physical infrastructure and developing required human resource for agricultural research and education. During 1978-1996, the World Bank through National Agricultural Research Project (NARP) financed the creation of 127 new zonal research stations and 222 additional substations covering most of India's agro-ecological zones in order to develop capacity of the SAUs to carry out area-based adaptive research.

**Figure 1: India's Agricultural Research System**



2.6 Long term growth in public agricultural research expenditure has gone through three phases, fairly rapid growth until 1968 (raising from Rs. 200 million to Rs. 400 million per year at 1980 prices), very fast growth from 1968 to 1980 (raising from Rs. 400 million per year to Rs. 1,300 million at 1980 prices) and then slow growth in the 1980s (rising from Rs. 300 million to Rs. 1,600 million per year at 1980 prices (Pardey and Roseboom, 1989, Pal and Jha, 1997). Associated with this growth in funding has been a phenomenal growth in the number of research institutions supported from these funds.

2.7 Despite this increase in funding, the share of ICAR in the total agricultural budget of central government has remained rather low, less than 6 percent. The percentage allocation to agricultural research and education out of the total plan outlay is steadily declining from 0.53 percent during 1969-1974 (IV Plan) to 0.29 percent during 1992-1997 (VIII Plan). This may seem puzzling because agricultural research had high rates of return, varying from 40 percent to 150 percent.

**Major Shifts in Research Priorities**

2.8 ICAR has a key role in shaping the national research system and in setting the national and state research and education agenda, although the state system has also become more mature and assertive. Research effort should strike a balance between types of research (e.g., basic, applied and adaptive), geographic regions (e.g., states/agro-ecological zones) and commodities (e.g., cereals/ rice, wheat, meat, milk, etc.). An assessment of ICAR resource allocation profile in relation to these variables is of considerable interest and importance.

2.9 Agricultural research has claimed nearly three- fourths of ICAR's resources since the 1969-1974 (IV Plan period). Agricultural education, which accounted for nearly a third of ICAR plan allocations in the seventies, now accounts for only 12 percent of expenditures. Most remarkable has been the growth in extension and transfer of technology activities, which now claims nearly 13 percent of ICAR plan funds.

2.10 Within agricultural research, the traditional focus has been on field crop research, which has accounted for one-fourth of the total research outlay. Since 1980, major expansion has taken place in non-commodity (other) research especially natural resources research. The share of horticulture and fisheries, in total research outlay has also been increased. Animal science research, after a period of expansion during 1974-1978 in the (V Plan), has remained at around 10 percent of the outlay of ICAR. In the IX Plan (1997-2002) to give the needed impetus to food security, sustainability, and equity issues, ICAR has allocated resources (Plan and Non-Plan outlay) as follows: field crops (25 percent), agricultural education (15 percent), animal science (14 percent), horticulture and extension (10 percent each), fisheries (6 percent), and natural resource including agricultural engineering, social sciences, and publication and information, and administration (20 percent) (GOI, 1996). However, the outlay being made available for the IX Five Year Plan of India (1997-1998 to 2001-2002) suggests that roughly agricultural R&D will get 0.52 percent of the agricultural GDP.

**Pay-Offs for Agricultural Research**

2.11 A number of studies using different methodologies have been undertaken to identify the costs and benefits of agricultural research in India. The studies vary in their coverage from very aggregate to a focus on individual commodities, and public and private R&D. The broad findings from these studies are as follows:

- The major determinant of productivity change in Indian agriculture has been the Indian public agricultural research system.
- The investment in agricultural research has yielded total returns far in excess of those realized in other developmental activities indicating that investments in agricultural research are among the most productive investments.
- Public sector research is as productive as private sector research.
- Research is responsible for 1/3 to 1/2 of the increase in total factor productivity, followed by market infrastructure.

2.12 Field crop research aiming to enhance production and productivity has been and continues to remain the focus of agricultural research in India. Treading this path is necessary, since the country's burgeoning population requires more food production (approximately 3-4 million tons annually) from a nearly fixed area. In an attempt to raise productivity, agricultural intensity has risen, leading to the degradation of land, water, and vegetation resources. As a result, natural resource research has gained momentum from 1980 onwards.

2.13 While this approach has stabilized production, it could hardly sustain growth. In response to this concern, importance of the social sciences has come to the fore, along with linkages between social and natural sciences. This has given rise to a paradigm shift in research methodologies. These changes have become noticeable through (i) farmers becoming active participants (ii) agricultural research becoming demand-driven and (iii) high-value agriculture, horticulture, and fisheries gaining prominence.

2.14 The evolution of broad research thrusts and subject matter and farmer orientation are given below:

**Table 1: Evolution of Research Thrusts**

| ***Research thrust*** | ***The period*** | ***Specific orientation*** | ***Scientist-farmer Interface*** |
|---|---|---|---|
| Production research (high intensity) | Up to 1980 | Genetics and plant breeding, soil fertility and fertilizers, irrigation | Farmers as passive recipients of technology |
| Natural resource research | 1980 onwards | Soil and water, with a focus on cropping system research | Farmers seen as source of information and technology design |
| Sustainability (environment) | 1985-1995 | Social sciences, processing, engineering biotechnology | Researchers recognizing the indigenous knowledge of farmers |
| High productivity, profitability, and sustainability | 1995 onwards | Markets, economics, international obligations, etc. | Farmers as participants in research agenda making |

## Indian NARS in Retrospect

2.15 The Indian NARS system has come a long way in building a complex infrastructure, and addressing the problems that have arisen (World Bank, 1990). But the basic problems of food and nutrition security, poverty, equity, employment, and falling quality of natural resources still persist. India has the largest number of people living below the poverty line (about 300 million), the largest number of illiterates (about 480 million), and the largest number of malnourished (270 million). Soft options to address these problems have been exhausted. New and difficult problems have also emerged, like sustainability of natural resources, increasing and sustaining exports through quality management, trade related adjustments following globalization, GATT agreement, etc.

2.16 The NARS is also facing system problems like unplanned growth, duplication, and overlap of mandates, loss of complementation, lack of resources, management problems, lack of operating expenses, inadequate funds to modernize/renovate buildings, offices, laboratories, field facilities, class rooms, libraries, etc., and lack of resources to train staff abroad and upgrade skills in frontier science/management areas. Other important issues to be addressed include SAUs' becoming strong and assertive at state level, entry of private sector and NGOs into agricultural research and education, etc. These problems/issues raise fundamental questions relating to the appropriateness of the structure and functioning of the NARS to current and future needs. In this context, an examination of strengths, weaknesses, opportunities, and threats (SWOT) of the Indian NARS assumes significance (ICAR, 2000).

**SWOT Analysis**

- *Strengths*
    - Well organized, diverse, integrated, coordinated research and education infrastructure.
    - Strong scientific human resource base.
    - Proven track record of technologies with high pay offs.
    - Vast network of training and technology dissemination system.
    - Strong partnership with other departments and NGOs.
    - Well developed linkages with other national and international institutions/organizations.
    - Ability to anticipate challenges and proven ability to meet them.
- *Weaknesses*
    - Low investments in research and regional imbalance in resource allocation.
    - Limited availability of trained human resources in frontier areas of science.
    - Inadequate involvement of other stakeholders.
    - Weak inter-disciplinary linkages.
    - Lack of system orientation in research.
    - Inadequate monitoring, review, and evaluation system.
    - Inadequate emphasis on socio-economic, policy, and gender-related issues.
    - Poor environment for scientific leadership development; inadequate personnel policies.
- *Opportunities*
    - Exploitation of genetic resources using bio-technological tools.
    - Exploitation of hybrid vigor in conventional and non-conventional crops.
    - Introduction and exploitation of underutilized and new crop species.
    - Improving quality of produce.
    - Minimizing post-harvest losses.

  - Tapping traditional wisdom in farming.
- *Threats*
  - Limited operational resources and outdated laboratory equipment in several laboratories.
  - Lack of performance oriented management and personnel policies.
  - Insufficient response to implementing O&M reforms.
  - Lack of synergies and complementarities.
  - Second-generation problems in technology generation and transfer.

**Challenges Facing Indian NARS**

2.17 By 2020, India's population is likely to be around 1.3 billion, and her contribution to satisfying overall employment needs is less likely to diminish significantly. Producing food to satisfy the hunger and to provide employment for buying food, and conserving the quality of natural resources remain the key concerns of agriculture. With opportunities for area expansion almost exhausted, the additional food output of 4 to 5 million tons/annum will have to come primarily through increased productivity. The immense pressure of man and the animal support system on India's natural resources has reached a saturation point. There is imperative need to develop agricultural activities with a discerning eye on their environmental consequences. The challenge for 2020 is "sustainable development of agriculture."

2.18 In Green Revolution areas, the intensive use of irrigation, fertilizers, and other agricultural inputs for crop production is now seen as a major cause of problem of soil salinization, groundwater pollution, nutrient imbalances, emergence of new pests and diseases, and environmental degradation. In fragile and marginal environments, including rainfed areas, rising biotic pressure and lack of suitable land management systems and inputs to realize optimum natural resource potential threatens agricultural sustainability. The consequence of the above is degraded lands, loss of biodiversity, soil erosion, waterlogging, pollution of water resources, deforestation, and overall environmental pollution and diminishing farming efficiency, resulting in falling productivity.

2.19 For efficient and sustainable agriculture, it will be essential to change from a commodity-centered approach towards a farming system approach. This will call for multidisciplinary format and interdisciplinary working. Researchers will have to work in full collaboration with farmers, who are both cause and victims of unsustainable development. The challenge is not only to offer solutions to raise production, but to offer them within a short time frame. This paradigm shift will call for designing new production systems aligned fully with the carrying capacity of natural resources in a region.

# 3. Forging Linkages

3.1 In the changing context for agricultural research, public research institutions such as ICAR cannot hope to succeed alone, but rather must seek complementary relationships with other research providers and its key stakeholders. ICAR has recently moved to strengthen a range of national and international relationships such as:

- Networks and collaborative research partnerships with the State Agricultural Universities (SAUs).
- Research agencies outside the ICAR/SAU system such as general universities, NGOs, and private foundations and firms, which are potential partners in research execution.
- Developmental agencies at the federal, state, and local levels, both in ministries and autonomous public and private bodies, for the purpose of technology transfer.
- Farmers, farmer organizations, agribusiness, and other potential clients of the research system for the purpose of establishing priorities and providing feedback to the research system. However, a farmers' organization that is apolitical and can really articulate the real needs of the farmers is yet to emerge.
- Foreign and international research and educational organizations for carrying out collaborative research as well as providing opportunities for India's NARS to export technology products and services.

**NARS in Relation to Regional Forums**

3.2 Indian NARS will have to integrate with the emerging global agricultural research system (regional forums like APAARI and IARCs, ARIS, GFAR, multinational R&D programs, etc.) to keep abreast with rapid advances in scientific knowledge and improve the cost effectiveness of technology generation by capturing "spill-ins" and through partnerships. It is imperative that globalized world work through turn-of-the-millennium, regional organizations like APAARI, supporting such groups in playing a key role in facilitating scientific and technological cooperation among the NARS; this could be achieved by providing neutral, apolitical forums that bring NARS leaders together to foster partnership, working together with IARCs that are already playing an important role in the region. APAARI may have to facilitate the building up of NARS and help in carrying out program implementation, technology development, commercialization, and research coordination, programming, prioritization, and policy formulation. For several reasons, Indian NARS has not taken a proactive role in developing ownership or taking advantage of these institutions. This outlook needs change.

**Status of International Cooperation**

3.3 The Indian Council of Agricultural Research (ICAR) and the Department of Agricultural Research and Education (DARE) are cooperating with various foreign governments, institutions, and multilateral agencies in the field of agriculture research and education through bilateral memoranda of understanding, protocols, and agreements (ICAR, 2001).

3.4 The major thrusts in cooperation with international institutions and under bilateral cooperation with other agriculturally developed countries are in: (i) new emerging technologies such as biotechnology, information technology, and remote sensing, (ii) rainfed agriculture with major emphasis on water-use efficiency and developing drought-resistant varieties, (iii) more efficient use of inputs, more specifically integrated nutrient management and integrated pest management, (iv) genetic resources conservation and improvement, and (v) post-harvest technology.

3.5 A number of multilateral cooperative programs are implemented under the auspices of the United Nations Development Program (UNDP), the Food and Agriculture Organization (FAO) of the United Nations, World Bank, ADB, the South Asian Association for Regional Co-operation (SAARC), the Swedish Agency for Research Co-operating among Developing Countries (SAREC) and the Commonwealth Agricultural Bureaus International (CABI), Ford Foundation, Rockefeller Foundation, and Australian Council of International Agricultural Research.

3.6 The Consultative Group on International Agricultural Research (CGIAR) supports a network of 16 international agricultural research institutes engaged in research, training, and dissemination of information on agriculture and allied subjects. The ICAR has entered into agreements with 10 research institutes and Centers of the CGIAR. The ICAR has also bilateral agreements with a number of countries, including the U.S., U.K., Japan, China, Russia, France, the Netherlands, Switzerland, Brazil, Egypt, Iran, the Philippines, Mongolia, Vietnam, Liberia, Ghana, Uzbekistan, Bangladesh, Nepal, and Mauritius.

3.7 Some of the gaps identified (ICAR, 1996) include lack of proper documentation of research needs for collaboration, particularly with Asian countries, and absence of a long-term human resource development plan in critical areas. India has also not taken advantage of opportunities for marketing its technologies and consultancies in human resource development fields, particularly in developing countries.

# 4. The Impact of CGIAR International Agricultural Research Centers on Indian Agriculture

4.1 The 16 international agricultural research Centers (IARCs) supported by the donor members of the CGIAR provide the world with a valuable source of innovation and knowledge for common action. They have played a pivotal role in the food production increases of the past 40 years, in contributions to the development of new crop varieties and continue in other areas at a significant rate. However, because of the simultaneous contribution of NARS, the output of CG Centers cannot be looked in isolation from the latter. Undoubtedly, initial development of high-yielding varieties of rice and wheat was a conceptual (short stature and responsiveness to inputs) revolution led by CG Centers. The developments that followed, however, were in full collaboration with NARS.

4.2 The contributions of International Crop Research Institute for Semi-Arid Tropics (ICRISAT), located in Hyderabad, India; International Rice Research Institute (IRRI), located in Manila, Philippines: CIMMYT, Mexico; IFPRI, Washington, D.C., U.S.; and ISNAR, Amsterdam, Netherlands, are highlighted below.

**International Crops Research Institute (ICRISAT), Hyderabad, India**

4.3 International Crops Research Institute for Semi-Arid Tropics (ICRISAT), established in 1972, is one of 16 Future Harvest Centers under CGIAR. It may be noted that CIMMYT and IRRI have helped to increase yield and production in irrigated agriculture. Vast rainfed areas with very low and uncertain yields and home of poor people were left out. Therefore, ICRISAT was established with a mission to help developing countries increase food security, reduce poverty, and protect the environment in the semi-arid tropics (SAT). It works to improve agricultural systems with special emphasis on cereal-legume rotation and on five crops prominent in the diets of the poor: sorghum, millet, groundnut, chickpea, and pigeon pea. ICRISAT staff work from eight locations in some of the poorest countries of the African and Asian SAT (Ryan and Spencer, 2001).

4.4 Impact assessment at ICRISAT systematically attempts to measure dimensions (food security, biodiversity, increased farm income, sustainable productivity, benefits to women, and spillover effects), most important to the poor and to the broad mission of CGIAR. These studies were led by ICRISAT scientists and/or NARS scientists supported by ICRISAT. The following are some of the highlights (ICRISAT 1999, 2001) under food security, increased farm income, sustainable productivity, planning and policy, and spillover effects (for estimates of impacts, see Appendix Table 1 to 3).

## Major Impacts and Achievements from the ICRISAT-NARS Partnership

### *Generic*

4.5 ***Food security.*** ICRISAT's genebank holds in trust over 113,000 germplasm accessions from 130 countries, preserving crop diversity and ensuring that plant breeders worldwide have free access to valuable genetic traits. Up to December 1999, ICRISAT distributed 408,311 germplasms of sorghum, pearl millet, chickpea, pigeon pea, groundnut, and finger millet in 32 countries of Asia.

- As a result of ICRISAT-NARS partnership, 405 cultivars were released in 170 countries, contributing to sharp increases in productivity. Of these 405 cultivars, 112 improved varieties have been released in India, and about l00 cultivars were released in other Asian countries.
- Downy mildew-resistant varieties helped rescue pearl millet production from the brink of disaster during epidemics in India in the 1980s and 1990s.
- ICRISAT-NARS developed improved pearl millet cultivars are grown in more than two-thirds of the pearl millet area in India.
- Wilt-resistant *Maruti* pigeon pea revived the crop in central India, and is called "a blessing and a miracle" by Karnataka farmers. Short-duration *Pragati* pigeon pea: enabled double-cropping, increasing net farm income by 30 percent and nearly doubling yield.
- ICRISAT developed the world's first pigeon pea hybrid, ICPH 8, which reached farmers' fields closely working with Indian NARS in 1991.
- Hybrid pigeon pea added another 30 percent in yield while being more resistant to drought than traditional varieties.
- In Andhra Pradesh, India, chickpea production registered a sevenfold increase following the introduction of new high-value Kabuli varieties. The additional produce is estimated to add U.S. $48 million annually to the state's gross domestic product.
- A groundnut production technology package, developed by the Vietnamese National Program with technical assistance from ICRISAT, has helped to double groundnut production in the country over the last 10 years.

- UPL Pn 10 (GL 24) groundnut variety occupies around 10 percent of the area of the Cagayan Valley in the Philippines.
- In Maharashtra, India, a high-yielding ICRISAT variety of groundnut and adoption of the broad-bed-and-furrow system of planting made it possible to quadruple production.
- Improved sorghum breeding contributed valuable traits to most of the varieties and hybrids grown across India.

4.6 *Increased farm income.* ICRISAT and the Farm Mechanization Research Centre of the Sri Lankan Ministry of Agriculture developed a new processing machine, which is small, inexpensive, and can be fabricated locally. The new machine can de-hull pigeon pea (and several other grains) to produce split peas *(dhal)*, and can also clean and grade the *dhal* produced, bringing higher market value to the grain.

- In the Barind region of Bangladesh, ICRISAT assisted in managing resource use to grow a second crop of chickpea where only one used to grow. Over the last decade hundreds of farmers' field demonstrations have seen chickpea area increase from about 200 ha in 1984 to over 10,000 ha in 1998. Six of the eight improved chickpea varieties in Bangladesh are ICRISAT-bred.
- A project involving the Philippine Council for Agriculture and Resources Research and Development, ICRISAT, and the Department of Agriculture on low-cost technology for storing groundnut seeds as an alternative to cold storage has been well adopted by farmers in the Philippines.

4.7 *Sustainable productivity.* Adopting IPM techniques, farmers in India, Nepal, Bangladesh, and Vietnam have greatly reduced the use of insecticide in pilot test areas, up to 100 percent on some farmers' fields.

- Discouraged farmers refused to cultivate chickpea in >75 percent rice fallows following the Botrytis gray mold (BGM) epidemic of 1997-1998 season in Nepal. ICRISAT scientists evaluated the performance of integrated disease management (IDM) practices with emphasis on farmer-participatory on-farm research, which included BGM tolerant varieties of seed. Increase in seed yield due to IDM was 2 to 6 times that of farmer's practice and resulted in higher incomes to farmers.
- Introduction and release of fusarium-wilt resistant and early maturing chickpea varieties in Myanmar have reduced losses due to wilt, drought, and heat stresses.
- Development of coconut ash as an alternative to chemical fertilizers reduced input costs by 24 percent in Vietnam.
- Polythene mulching improved germination, seedling vigor, and crop growth in winter-sown groundnut in northern Vietnam, and combined with high-yielding varieties, produced 50-80 percent more yield than non-mulched plots.
- With improved watershed management technology, up to 4 tons of grain per hectare can be harvested from drylands, soil loss can be reduced by 60-75 percent, and rainwater loss through runoff by 50-60 percent. Also, the recharge of groundwater increases by more than 40 percent. Supported by the Asian Development Bank, ICRISAT in partnership with NARS is demonstrating this package to the farmers of India, Thailand, and Vietnam. However, the sustainability of technology has not been

satisfactory since the moment IARCs/NARS support is withdrawn, the program collapses.

4.8 *Research prioritization and policy and planning.* Systematic efforts with the association of Indian NARS, are made towards research prioritization and impact assessment

- Compiles, cleans, and maintains District-level database of farming systems for policy and land-use planning across India.
- Village-Level Studies (VLS) conducted in India provided better understanding on household economics and farmers needs that helped in technology design and policy formulation.

4.9 *Spillover effects.* Spillover effects include:

- S 35 (sorghum) was developed in India and adopted in Cameroon and Chad.
- ICMV221 and WC-C75 were originally developed for India; ICMV 221 is now adopted in Kenya and Uganda and WC-C75 in Zambia.
- Millet "Iniadi" germplasm from Togo became the most popular open-pollinated variety in India.
- Okashana I was developed for India and released in Malawi, Zimbabwe, Namibia, and Botswana.
- ICG221, developed for India, spilled over into Swaziland.
- ICPL87091, developed in India, was released in Kenya, Tanzania, and Uganda.

***Specific Impact: Crops***

4.10 The following crops have been impacted:

- *Sorghum*
  - Significant impact in parts of Africa.
  - Great ***impact in India:***
    - >80 percent (4 m ha) rainy season area under hybrids.
    - >50 hybrids including those developed by NARS under cultivation.
    - >70 percent hybrids from private sector.
    - >75 percent private sector hybrids based on ICRISAT-bred material.
    - MH 179, an ICRISAT hybrid, once became a predominantly cultivated hybrid in India till other early maturing hybrids were evolved by the national program.
- *Pearl Millet*
  - Significant impact in parts of Africa.
  - Great impact in India:
    - >60 percent area (6 m ha) under hybrids.
    - >70 percent hybrids under cultivation.
    - >80 percent hybrids from private sector.
    - >80 percent of all hybrids based on ICRISAT-bred material.
- *Chickpea*
  - Substantial impact in India (e.g., Andhra Pradesh):

        - From 48,000 ha in 1989 to 140,000 ha in 2000.
        - 25 percent area under two ICRISAT-derived varieties.
        - Substantial impact in Canada.
        - Total area 280,000 in 2000.
        - ICRISAT-derived variety Myles in 140,000 ha (net annual value U.S. $50 million).
        - Total area increased to about 500,000 ha in 2001.
    - Significant impact in Bangladesh, Myanmar, and Ethiopia.
- *Pigeon pea*
    - Two ICRISAT–derived varieties on >0.8 m ha in three Indian states.
    - Four ICRISAT-derived varieties on about 85,000 ha in southern and eastern African region emerging as an important legume for multiple uses in China (3,000 ha in 2000).
- *Groundnut*
    - Several varieties adopted for seed-village programs in India
    - IDM research-cum-seed production of four ICRISAT-derived varieties in Deccan plateau: expected adoption on 0.5 m ha in 2003
    - CG 7 on >30,000 ha in Malawi and adopted by 50 percent farmers in Zambia; ICGS 36E on about 20,000 ha in Mali
    - A cost-effective aflatoxin diagnostic tool currently being used by a poultry feed manufacturer with annual turnover of more than U.S. $ 4 million
    - Effective control measures of peanut stem necrosis disease adopted on 0.5 m ha in Ananthapur district in 2001

### *Village Level Socio-Economic Studies (VLS)*

4.11 *Impacts on technology design and development.* VLS has led to a better understanding of the constraints and opportunities in the SAT. It established that:

- Adoption rates are closely related to the degree to which households are integrated into the wider product market. This finding led to the strengthening of work on seed systems development and market integration.
- It is preferable to address factor market distortions and imperfections to benefit small and marginal farmers rather than search for specific technologies relevant to them. Growth in income among the poor will not necessarily ensure nutrition security: other measures are required.
- The "protein gap": conventional wisdom is questionable. It has influenced breeding strategies not only in ICRISAT but also in the National Agricultural Research System (NARS).
- Land fragmentation is not a major constraint to improving crop productivity and has risk-diffusion benefits: The need to take into account current landholdings and fragmentation in watershed approaches was recognized.

### *Impacts on Policy*

4.12 The Indian government was influenced to take the following actions:

- Not to hand over wasteland to private industry for forestation.
- To recognize the need for more flexible lending policies for dryland agriculture.
- Findings on the scope for credit societies and chit funds to finance agricultural investment in the SAT had an effect on rural credit policy.

***Impacts on Development Investments***

4.13 Development investments were also strongly impacted:

- Findings on crop yield insurance in India influenced the design of crop insurance programs.
- In India, findings were used to incorporate development components in relief works, especially those pertaining to minor irrigation and water harvesting structures.
- On the basis of VLS data sets, the importance of common property resources in the incomes and nutrition of the poor were documented.
- Program components in biofuel and fodder production were devised based on findings on common property resources.

***Contributions to Science***

4.14 The contributions of ICRISAT to the science in NARS as a premier pre-breeding genetic enhancement center included systematic screening for resistance to various abiotic and biotic stresses and resulted in the identification of numerous sources of resistance to biotic and abiotic stresses in cultivated crops of groundnut, millets, etc. The availability of these sources of resistance has reoriented breeding objectives not only in India but also in all other countries where there are active breeding programs in these crops. It may be noted that providing such a knowledge service, particularly in germplasm management, is difficult in NARS due to resource crunch and bureaucratic rules and procedures. IARCs have a distinct comparative advantage here.

***Contributions to Poverty Reduction***

4.15 ICRISAT technologies have also contributed to poverty reduction and societal welfare (ADB, 2000). The following two examples illustrate this.

4.16 The first study focused on the impact of ICRISAT pearl millet technologies in Rajasthan, (India). Some major indicators of welfare changes found in key informant surveys included (i) change from *kuacha* (traditional) to *pucca* (modern) houses, (ii) better clothes, (iii) self-sufficiency in food, (iv) increased spending on household essentials due to increased availability of cash, (v) higher spending on education of children (including girls), (vi) greater on-farm investments, (vii) more employment opportunities, and (viii) increased cropping intensity. It was further revealed that benefits accrued due to several interrelated changes:

- Increased yields enabled farmers to retain more for consumption and spend less on purchase of food grains. Also, farmers have enough left over after retaining product for self-consumption to sell in the market and earn cash incomes.

- Increased yields enabled farmers to decrease the area under pearl millet cultivation and increase the area for cash crops, especially for those that require less water and can germinate and mature utilizing soil residual moisture.
- In villages where ICRISAT cultivars have been introduced, the choice of varieties has changed significantly. Earlier, the choice was between *desi* (local) and improved cultivars and hybrids. Now, the choice is essentially between ICRISAT open-pollinated varieties and private sector hybrids, many of which have ICRISAT parents.

4.17 In the second study, tracking poverty-reduction impacts of adoption of groundnut production technology in Maharashtra, India, before and after analysis revealed that a large number of welfare changes have occurred:

- Changes in cropping pattern (more diversified cropping system, larger basket of commodities).
- Bringing more land under cultivation (increased capacity to invest, more crop options).
- Increased area under cultivation during *rabi* (post rainy season) and *kharif* (rainy season).
- More area under irrigation (availability of sprinklers, pump sets).
- Reduced dependence on risky crops and crops requiring more inputs.
- Increase in yields.
- Increase in income and profits.
- Generation of permanent and semi-permanent assets, including land, livestock, pump sets, and sprinklers.
- Changes in land holding pattern (some agricultural laborers have bought land, while marginal farmers have increased their landholding).
- Increase in wages for agricultural workers.
- Increased availability of employment throughout the year.
- Improved choice of work and workplace.
- Wider basket of commodities consumed by farmers as well as agricultural laborers.
- Reduced spending on food items.
- Increased capacity to support nonworking family dependents.
- Reduction of indebtedness.
- Availability of credit.

4.18 Some results from these surveys show a high degree of correspondence between the results of improved agricultural productivity and welfare measures for target poverty groups. Some basic conclusions that can be drawn from the second study are:

- Adoption of groundnut production technology (GNPT) has contributed directly to increases in income and yields.
- Greater stability of the cropping system has been achieved.
- Indirectly, GNPT has improved food availability, improved nutrition, led to crop diversification, and increased ownership of assets.
- Assets acquired for GNPT are being used for other crops and have enabled cultivation in other seasons.

- Initial benefits in the form of higher profits and income were reinvested to obtain long-term benefits and stabilize the farming system.
- Stability of the farming system increases the freedom of farmers to take decisions regarding cropping pattern (cash versus subsistence crops or market versus subsistence orientation, investing in production versus investing in education, housing, household assets, etc.).
- Positive changes have occurred in the area of labor. Out-migration of labor has been replaced by in-migration of labor. Employment opportunities for women have gone up.
- Credit ratings have improved.
- Government programs have enabled purchase of accessories. In addition, government programs targeted the village studied after its visibility improved due to technology adoption and the resulting impact.
- General improvements have occurred in health, sanitation, housing, and common facilities, as well as an improvement in the level of food security, especially for marginalized groups in the village.
- Feeling of empowerment: general improvement in self-esteem, confidence, ability to innovate, etc. Empowerment is also reflected in an increased choice of crops that are cultivated, choice of investments, and access to credit, information, and agents of various government bodies.
- Reduction in the social distance between groups of different social status. Feelings of social isolation both within the community and in reference to the wider world have decreased. The community has become more socially inclusive, with greater interaction between members of different social categories

4.19 However, such success stories are very few as it is generally true that the power of technological solutions to solve poverty problems is extremely limited in the absence of economy-wide growth, rural-urban migration, etc.

***Contributions to Research Planning***

4.20 Yet another major contribution of ICRISAT relates to systematically influencing the research planning and impact assessment culture within ICRISAT, NARS, regional organizations like APAARI, and even IARCs. This movement is now being picked up by NARS, regional forums, etc., to focus research, optimize use of research resources, and attract more funding from donors, including national governments that in recent years have insisted on such exercises for granting funds.

4.21 To sum up, the contributions of ICRISAT to the agricultural progress and rural development in India are important. However, more concerted efforts are needed to develop collaborative programs so that the limited budget available in the national as well as the international agricultural system is optimally utilized. Ideally, the studies on impact assessment require full collaboration and endorsement of NARS. Most of the previous impact studies were commissioned and conducted by ICRISAT, a fact that leaves an impression of bias, whether or not they are actually biased in fact. Nor are there many studies that have been conducted independently by NARS, with findings substantiated through comparison with those obtained by ICRISAT.

4.22 The fact remains that much needs to be done to upscale the application of results of point studies. It should be noted that not many examples or evidences are available on how strategic research at ICRISAT had helped solve specific resource management or sustainability issues over a broad geographic range. Further, most problems confronted in dryland areas call for infrastructure and development works. Hence, the impact of any research will remain partial and perhaps unsustainable until the efforts of researchers and development departments are interfaced. Since local people have to live with the consequences, developing partnerships with them is necessary in initiating research and development efforts and maintaining them.

4.23 Some of the specific areas where renewed thrust (with emphasis on strategic research) and complementary role between Indian NARS and ICRISAT is needed include the following:

- Resistance breeding against diseases is currently the main theme for pearl millet hybrid development. Besides, there are requirements for early maturity, bold grains, and high tilling for dry farming conditions and dual-purpose hybrids with high grain and fodder yields.
- In case of sorghum, challenges relating to abiotic and biotic stress alleviation, germplasm diversification, and superior grain quality in *rabi* sorghum should receive more attention.
- In case of pigeon pea, after pioneering research work on hybrid (ICPH8) by ICRISAT, a national program was developed PPH4 and CDH 1 and released for commercial cultivation in Punjab and Tamil Nadu, respectively. These hybrids are successful in rainfed conditions. But far more efforts are required for achieving sustainable higher productivity and area gains favoring hybrid pigeon pea.

4.24 ICRISAT has several comparative advantages in capability to understand the sustainability consequences of technological interventions, “new sciences,” investment in geographic information systems and simulation modeling of soil, water, and nutrient interactions, and expertise to deal with socioeconomic aspects including analysis of gender issues, project prioritization, monitoring, evaluation, and impact assessment. It should serve as a technology incubation and demonstration center, integrated natural resource management center, etc. It has to advance, validate, and supply models and methods in relation to agricultural production — including simulation models, biotechnology remote sensing, ICT, precision farming, GIS, GPS, space technology, ground truthing, etc. In other words, it has to mainstream production problems into the research paradigm and provide workable models, methods, and approaches to the national system for further modification and adoption.

4.25 ICRISAT has also comparative advantages in expertise and facilities on bio-technology, information management systems, and participatory methodology. Each of these holds the promise to fundamentally alter the probability of success of research in specific areas. Therefore, with collaboration with NARS, it is possible that these capabilities could be shared with the National Agricultural Research System in developing research proposals and human resource development and skill upgrade. The research infrastructure built at ICRISAT, Hyderabad, is a unique facility that the National Agricultural Research System can make use of. Similarly, a very comprehensive and vast network of ICAR and SAUs institutions built throughout the length and breadth of the country will be useful to ICRISAT for assessment and refinement of its technologies. It may be very difficult to build an infrastructure of the type

ICRISAT has and similarly it is equally difficult for ICRISAT to build an infrastructure of the type that Indian NARS have. The wisdom lies in sharing these unique strengths to solve the intransigent problems confronting agriculture in a true partnership mode.

**Contributions of International Rice Research Institute (IRRI), Manila, Philippines, to Rice Productivity Gains in India**

4.26 The contributions of IRRI to the Indian rice program are highly significant. But one must recognize the complexity and multiplicity of IRRI's contributions, particularly in rice varietal improvement. Whereas the first generation of modern varieties was based to a large degree on international research, subsequent varieties have involved collaboration among national and international centers. Indeed, it makes little sense to discuss IRRI's impact in isolation from the work of the NARS (Hossain *et al.*, 2001).

***Research Inputs and Investments***

4.27 There is an apparent increase in the number of scientists (those with MS and Ph.D. degrees) involved in rice research during 1983-1999. In India, their number increased from 546 in 1983 to 625 in 1999. In other words, number of scientists per million ha of rice land increased from 13 in 1983 to 15 in 1999. At IRRI, the number of scientists increased by 53 percent during 1980s, but declined marginally in the 1990s (except crop improvement, where it has increased). This decline has a consequence of general staff reduction programs enforced to downsize the institute. In 1998 India invested about U.S. $ 12.3 million on rice research. NARS in South and Southeast Asia currently spend about U.S. $ 36.2 million per year for rice research, almost equivalent to the approximately U.S. $ 34 million that IRRI spent in 1999. IRRI allocates 37 percent of its resources for genetic enhancement and breeding programs. In India, on the basis of scientists engaged, the share of genetic research comes to about 36 percent. For the South and South East Asia, it can be assumed at 40 percent.

***Varietal Improvement and IRRI's Contributions***

4.28 There appears to be a relentless flow of varietal releases. Over time in an average region, NARS released 50 varieties per year from the mid-1970s until the mid-1990s. India, with the largest rice area released 211 varieties during 1971-1980 and 347 during 1981-1990. The data across the countries indicate an active and productive research effort throughout the region.

***Genealogies of Released Varieties — IRRIS Contributions to Varietal Improvement in Different Forms***

4.29 *IRRI developed varieties.* Of the 2040 released varieties, 219 (10.7 percent) were known to be IRRI lines released directly in other countries (without further breeding). In India, it may be 10 percent (Appendix Table 4). As a percentage of the total released varieties, IRRI-developed varieties appear to have reached their highest level in the 1970s, when about 18 percent of all releases in region were IRRI-developed lines. This corresponds to a period during which the first brand of modern varieties was developed that displayed effective resistance to a number of important diseases and pests. In subsequent years, the fraction of IRRI-developed varieties has fallen substantially; in the 1990s, only about 3 percent of varieties can be identified as those originating from direct IRRI crosses.

4.30 *IRRI materials as parents*. It is estimated that about 31 percent of varieties came from one or more parents developed at IRRI. Thus, including IRRI-developed lines, about 42 per cent of the released varieties originated from one of more parents developed at IRRI. In the case of India, it is 33 percent. It may also be noted that, in India, the use of IRRI parents has fallen perceptibly since the early years of the Green Revolution suggesting a change in the respective roles of IRRI and the national program.

4.31 *IRRI provision of other ancestors.* As NARS capacity grew, IRRI increasingly provided them with elite lines for use in their breeding programs. These intermediaries are used as parents of released varieties but sometimes appear as grandparents or more remote ancestors. This has begun to create a pool of genetic resources that belong to IRRI ancestry but not at the parental level. Excluding IRRI crosses and varieties with IRRI parents, this pool accounted for 7.9 percent. In case of India, it is estimated at 9.5 percent.

4.32 Thus, the overall contribution of IRRI (including all three categories) to the improved germplasm released by NARS increased from 16 percent in the 1960s to over 60 percent in the 1970s, thereafter remained at a level of 50 percent. Based on a random sampling of crosses made at 28 different rice experiment stations in South and South East Asia, it is found that many breeding programs made extensive use of recently developed IRRI lines. IRRI also played the role of source of many traits, from single trait of semi-dwarfing gene in the initial stage to bundles of other useful traits and characteristics.

### *Adoption and Use of Improved Varieties*

4.33 By the late 1990s, nearly 75 percent of the rice area in Asia was planted with improved (HYVs)/MVs. For India, the coverage is 74 percent. The analysis of area planted to different varieties (55 important, 5 each in 11 countries) indicated that 18 were IRRI crosses, 11 were derived from IRRI parents, 7 had other IRRI ancestry, and 16 had no IRRI ancestry; 12 of them are, in fact, traditional varieties. Although IRRI crosses constituted only one third of the varieties, they covered 40 percent of the planted area. The popular IRRI varieties were generally represented by IR-64, IR-8, IR-20, IR-36, IR-42, IR-50, and IR-66. Mashuri, a variety introduced in early 1960s, and Swarna, a selection from Mashuri in the early 1980s in India, are the most popular varieties grown in the rainfed low lands of several Indian states, Nepal, Bangladesh, and Myanmar. It is reported that about one-third of the widely grown varieties were introduced from IRRI, and most of the rest were developed locally, with varying degrees of IRRI germplasm. In another study on ancestors, it is estimated that 45 percent originated from IRRI materials, 23 percent from India, 7 percent from Sri Lanka, and 4 percent each from Indonesia and Thailand.

### *Training and Information Exchange*

4.34 More than 900 Indian researchers have participated in educational and training programs at IRRI. India contributes the most post-doctoral researchers to IRRI, with more than 180 scientists having conducted their post-doctoral research since 1962. Hundreds of

Indian scientists have participated in IRRI conferences, workshops, and monitoring tours over the last 14 years (IRRI, 2002).

### *Contributions of Indian Scientists to IRRI*

4.35 The contributions of Indian scientists to IRRI programs are many. Fifteen Indian scientists have worked as internationally recruited staff (IRS) members at the IRRI headquarters in Los Banos, Philippines. Eight others have worked in IRRIs outreach programs outside the Philippines and 137 have served as visiting and post-doctoral scientists.

### *Impact of IRRI to Rice Economy*

4.36 It is difficult to quantify the production impacts of international rice research, disentangle the impact of research from the increased use of inputs and difficult to attribute research impacts to particular programs or institutions. Nonetheless, the story of the Green Revolution in rice over the past 40 years stands as a success of monumental proportion. According to FAO data, 1.6 billion people inhabited developing countries of Asia in 1961. In the next 4 decades, population rose to 3.4 billion people, a growth of more than 100 percent. During the same period, rice area expanded from 107 to 139 million hectares, an increase of only 30 percent. During the same period rice production grew by 170 percent from 199 million metric tons in 1961 to 540 million metric tons in 2000. About 83 percent of the production increase was attributable to growth in yield from 1.85 metric tons/hectare to 3.9 metric tons/hectare. It is the more efficient production that has brought down the price of this staple by about 50 percent in real terms over the last 3 decades.

4.37 It is of interest to note from a recent study of Janaiah et. al (2002) that about 64 percent of overall genetic improvement for the released modern varieties (MVs) in India was contributed by improved germplasm of the national system while the remaining 36 percent came from international spillovers. It is also stated that the direct releases of IRRI's material covered about 12 percent of total rice area in India.

4.38 An analysis of costs and returns of traditional and modern varieties indicated that the net yield gain is 0.94 t/ha equivalent to U.S. $150 at the price prevailing in the domestic markets. For South and South East Asia, the estimate of net gains from the adoption of modern varieties stand at about U.S. $10.8 billion, which is nearly 150 times the annual investment made in the rice research by IRRI and NARS together. Although these calculations are somewhat crude, they clearly indicate the enormous rate of return on investment in rice research in Asia.

4.39 The other benefit of genetic improvement not included in the calculation relates to reduction in the growing period for the modern varieties a factor contributing to increase in cropping intensity. The data from IRRI's experimental farm show that the crop maturity period has been reduced from 135 days for IR 8 and IR 5 to 114 days for IR 64, increasing the yield per day from 47 kg for IR 8 to 60 kg for IR 64, for the dry season. In the wet season, the yield per day increased from 35 kg for IR 20 to 43 kg for IR 72. It is thus concluded that so long as international research contributes in a measurable degree to increase in rice productivity, the economic pay offs will be overwhelmingly large. The farmers' preference to grow IRRI varieties or their derivatives clearly shows that there is a measurable contribution.

4.40 There appears to be some evidence of a slow down in the rate of varietal releases by national programs; at the same time, there is hardly any indication of a declining role of international institutions in generating these released varieties. IRRI remains an important source of germplasm both for direct application by farmers and as elite material for application in breeding programs. IRRI-developed and derived materials account for large fraction of area planted in South and South East Asia, and their overall importance shows no sign of fading. Further, the rice Green Revolution, far from having finished in the 1970s, has continued well into the 1990s and beyond. The data suggest a far more protracted episode of technological change. If the diffusion of modern varieties had halted in 1980, the area currently planted to MVs would be about half of what it is today. The study of diffusion of MVs in the 1980-2000 period indicate the development of new varieties with new characteristics — primarily disease and pest resistance, improved grain quality and shorter duration of the crop.

4.41 Future collaboration of Indian NARS with IRRI may have to focus more on improving nutritional quality of rice (e.g., golden rice), functional genomics, hybrid rice, etc., besides continued efforts towards capacity building, exchange of germplasm ,etc.

**Role of ISNAR in India**

4.42 As an integral component of its mandate to assist the developing country's NARS in improving research management efficiency and effectiveness, ISNAR undertook several major activities in India. They are summarized below.

***Information Management***

4.43 *Development of MIS.* While the Indian NARS is faced with greater challenges for meeting the qualitative and quantitative demands for food, fiber, and fuel of the ever-increasing population, the availability of research resources is not commensurate with the requirements to meet the emerging needs of sophisticated and modern agricultural research programs. That is why yields in farmers' fields remain far behind the national demonstrations or yields obtained on researcher managed fields. Realizing the fact that efficiency in the use of such finite resources can be brought about by sound decisions based on quality information in a timely way, the system looked for a computer-based management information system (MIS) for agricultural research. ISNAR came to assist the System in developing a suitable methodology for this purpose.

4.44 With Asia Development Bank (ADB) support, ISNAR was instrumental in developing a basic framework for information management. The methodology, initially developed by ISNAR with Sri Lanka as a test case, was first tested for its utility in the developing countries in South Asia through a regional workshop in India in 1990. On the basis of the experience gained and the feedback received from the workshop, ISNAR came out with a methodology called INFORM. Because of similarity in mandate, NAARM was identified as the nodal center for carrying out INFORM-related activities in India. The methodology was popularized by NAARM through a series of training programs for the scientists and technicians directly associated with the development and management of MIS in ICAR and SAUs, and workshops to sensitize the decision makers on the utility of MIS. On the basis of feedback received from the Indian and other developing country NARS, ISNAR developed an exclusive software called INFORM-R. It was proposed to train Indian scientists in using this software for information management. This needs to be pursued.

4.45 ***Consultancy service to ICAR.*** ISNAR provided consultancy service to ICAR, in association with premier Government of India IT institutions like NIC and ERNET, to develop an information system amenable for networking in the country. This finally led to the creation of ARIS in ICAR and SAUs.

4.46 ***Policy support.*** On the basis of experience gained, NAARM was invited by ISNAR to contribute in policy-level planning pertaining to information management as follows:

- International Workshop on INFORM-R at ISNAR in December 1996.
- ISNAR-JIRCAS Project Planning Meeting on New Technologies for Agricultural Research in Japan, March 1997.
- International Workshop on Information Policy for Agricultural Research at NAARM in December 1997.
- NAARM's participation in these programs helped ISNAR strengthen its information management activities.

4.47 ***Centers of Excellence in IT/IM.*** In order to take advantage of numerous opportunities opened up by the IT investment through ARIS in ICAR and SAUs, ISNAR proposed a three-year project to establish "demonstration sites" at SAUs that would become "Centers of Excellence" in IT/IM. These centers would focus on research, education, and training and extension in agriculture. In the meeting organized by ISNAR at M.S. Swaminathan Research Foundation in 2001 to work out suitable implementation strategies, senior faculty members from NAARM took part in the deliberations.

### *Role of ISNAR in HRD Activities*

4.48 Because of similarity in mandate, ISNAR placed one of its senior staff at NAARM to assist the academy in its HRD activities. The ISANR staff member participated, as resource person, in various senior-level training programs organized by the academy

### *Role of ISNAR in Supporting On-Going Programs at NAARM*

4.49 *Distance education.* Realizing the fact that distance training is a potential option to "reach the unreached" in research stations in rural areas and to provide in-service training opportunities in a cost-effective manner, ISNAR collaborates with NAARM in the DFID-funded project. The joint project is taken up in two phases: applied research and adaptive research. During the first two years, 1998-2000, the applied research component was completed; and in the second phase adaptive research component has been launched by developing suitable training modules focusing agricultural research on poverty alleviation. On a pilot scale, the modules are being field-tested with a target group of 60 scientists in four participating institutions. Based on the experience, it is proposed to modify the distance training program under NATP.

4.50 *Performance assessment.* In order to build the capability of NAARM in the area of performance assessment and accountability enhancement of NAROs, ISNAR will provide consultancy services to NAARM in developing methodology as well as relevant resource material for training under this program. One NAARM faculty member has already been trained at ISNAR.

4.51 *Research proposal writing.* With a view to developing necessary skills in scientists in writing sound research proposals for attracting funding from donor agencies, this proposal was developed by ISNAR in collaboration with NAARM. The training program may be organized by ISNAR at NAARM in the near future.

4.52 Working with ISNAR, though scientifically satisfying, did give rise to some administrative uncertainties. True spirit of working together by participating and facilitating method was lacking due to directive style followed by ISNAR. In a strong NARS like India, ISNAR scientists continued to work in a fashion that they adopted with fledgling NARS in other developing countries.

## Role of IFPRI in India

### *Policy Research in Indian Agriculture*

4.53 Policy research in Indian agriculture by institutions under NARS formally began with the establishment of National Centre of Agricultural Economics and Policy research under ICAR in 1991. The center's research focuses on five theme areas of technology policy, sustainable agriculture systems, supply, demand, market and trade, institutional change, and growth and adjustment. This center not only provides policy advice to ICAR but also to other related institutions, such as SAUs in the NARS.

4.54 The relevance of agricultural economics and policy research for the NARS in the present context is enormous. In particular, the developments during the last few years have brought out (1) the importance of an extended system of economic evaluation of research within the NARS, (2) the requirements of evaluating the impact of resource degradation, and (3) the imperatives flowing from the exposure of Indian agriculture to international trade. It is necessary for the system to adapt itself to these changed priorities.

4.55 Although, by and large, the earlier initiatives did make a qualitative change in the decision making environment in the NARS in general and the Council in particular, certain gaps are still evident. For example, although emphasis was given on involving agricultural economists in major agro-biological research, the success has been less than adequate. Similarly, the efforts made towards institutionalizing PME mechanisms in the NARS remain incomplete. Several research questions relating to sustainability of agricultural systems, profitability of farming under WTO regime, future research agenda, etc., are yet to be answered. Moreover, the lack of adequate and reliable databases and analytical protocols is proving to be a serious constraint to good agricultural economic and policy research. The interface with institutions outside NARS and beyond India remains weak. All this hampers capacity building both for advanced research work and in the teaching of agricultural economics. These gaps and gray areas must engage the priority attention of agricultural economists in the coming years.

4.56 *Some concerns*. Until recently, India has depended mainly on the seed-fertilizer-chemical approach to productivity growth in agriculture, with emphasis on wheat and rice. The research effort has progressively been extended to other crops and to non-crop agriculture. Although this has led to considerable modernization of India's overwhelmingly small farm agrarian economy, there are certain signs that this effort needs to be intensified and extended to cover new concerns. Thus, total factor productivity growth has decelerated during the 1990s, mainly because yield growth has slowed down in the case of almost every major crop and some of the major production systems appear fatigued.

4.57 There are many reasons for this. Public investment and capital formation in agriculture has been declining since the 1980s, and this trend has accelerated during the 1990s, limiting the spread of necessary infrastructure. Also the seed-fertilizer-chemical approach to productivity growth gave inadequate emphasis on sustainability issues, and there was inadequate environmental support for a sound farming system. Farmers have themselves given up some of the time-tested, wise traditional practices that had earlier supported sustainable agricultural development. This has led to rapid depletion of soil fertility and increase in the pest-disease complex. Related to this is the removal of vegetative cover, resulting in disturbance of the biological equilibrium. All these have led to an increase in unit costs of production and decrease in product quality, making Indian agriculture less competitive in the international market.

4.58 With GATT agreement and WTO in operation, Indian agriculture with all its structural weaknesses must compete with highly commercial agricultural systems of the developed countries. The country is thus facing an uncertain period not only in the technology area but also the economic scenario confronting agriculture. These uncertainties have created disequilibrium and have led to "development restlessness" among Indian farmers, scientists, planners, and policy makers.

4.59 This has increased the importance of advice from economists regarding agricultural policy and assessment as to which investments in agriculture are most appropriate. Economists need to advise government on policy and on the best means to provide support to farmers; they should also advise farmers about the profitability of technologies recommended through Krishi Vigyan Kendras (KVKs) and advise the research system itself on whether what it is doing is right and relevant. However, the system, as it currently exists, needs to be strengthened to cope with these requirements.

4.60 During the coming years a major effort will be required for this. In view of the enormity of the challenge and the limitations of the existing economics components within the NARS, this can be only be accomplished if NARS works jointly with other institutions. In this, the Ministry of Agriculture has a special responsibility to coordinate with NARS the functioning of agencies under it. In addition, there is a need to build the cadre of agricultural economists within the NARS and upgrade the skills of the existing cadre.

4.61 *New thrust areas*. In addition to the earlier initiatives identified above, certain new directions and needed strategies have been identified. A few are elaborated below.

4.62 We need to recognize the specific R&D support required for the three major farming situations: rainfed agriculture, well (private) irrigated agriculture, and canal (public) irrigated agriculture. In case of rainfed agriculture, adequate attention must be directed towards use of hybrid varieties, proper soil and water conservation measures on watershed basis, use of adequate amount of organic manure, adoption of improved agronomic practices farm mechanization, and mixed farming and mixed cropping practices with tree crops as necessary components. Under well-irrigated farming situation, with water use efficiency as the central point, profitability of crops along with economic use of water, avoidance of water-intensive and mono-cropping systems, and application of organic manure should be kept in view, among other considerations. In the case of canal irrigated farming, water supply discipline, drainage system management, proper crop planning and rotation, and balanced use of fertilizer with organic manure should be emphasized.

4.63 A wider purview of technologies impacting on all components of the farming system and judicious use of technologies must be given adequate attention. A combination of the best of modern and traditional practices — crop rotation, mixed cropping, mixed farming, use of organic manure, and tree crops as options, particularly in dry farming areas — are some examples in this direction.

4.64 The Indian livestock and fishery sector holds considerable potential both in the domestic and international markets. These sectors along with horticulture will bring about next food revolution in India. The high income elasticity of demand for livestock and fishery products and the growing health consciousness among consumers are sure signs that the demand for these products will grow in the coming years. Competition from foreign products is expected under liberalized trade regime, calling for production and marketing efficiency at both the farm and processing levels, improvement in the quality of products and their keeping quality, improvement in nutritive value of products, and innovative product development. Indian agriculture is undergoing substantial change, with fruits/ vegetables, flowers, spices, medicinal plants and animals, and specialty crops, having grown much more rapidly than forecast crops over the last decade. This is clearly an area where agricultural economists must put in greater research, both on farm-level economics and on the required backward and forward linkages.

4.65 At the micro level, there are many farm level studies on the economics of fruit/vegetable and livestock/poultry production. But these need to be consolidated and linked to other studies that relate to linkages, both in input supply and in processing and other post-harvest issues. For this an all-India effort is required. This is necessary because the potential for diversification and of mixed farming requires a specific systems approach.

4.66 In particular, development of processing and agro-export zones will require both state governments and industry to identify compact regions with the greatest future potential; banks will need reliable cost estimates for credit plans. Policy makers will thus require projections of future supply-demand balances and an idea of which agro-economic regions are likely to diversify most and from which crops. Since much of the technology in these crops are being diffused through private sector seed companies, it will be necessary to evaluate the economics of these technologies, benchmark these against technology available from public sources, examine the incidence of unethical practices such as in the distribution of spurious seeds and pesticides, and identify the post-harvest constraints.

4.67 Research will have to play a major role in our search for sources of productivity growth and efficiency in agriculture, and go beyond this. It has to focus not only on yield growth but also on yield stability, unit cost reduction, and quality augmentation. In addition, price and other market uncertainties will need to be quantified, the effect of these on farmers' decisions analyzed, and advice given to both policy makers and farmers on how to handle such risks. Only by bringing such new issues into focus can the agricultural economists in the NARS provide the cutting edge for Indian agriculture to be competitive.

4.68 Rebuilding the natural resource base to provide a sound environment to support farming is a critical part of this new direction. The need to develop sustainability indicators has assumed critical significance. This should be piloted both at farm level and community level. Unless this is done, it will not be possible to achieve sustainable agricultural growth while meeting the challenges of competition in both domestic and international markets. Restoration of soil health and fertility through appropriate technology package, including vegetative cover, would be crucial. At the community level, vegetative cover around the village, on main roads leading to farms, on tank / canal bund, and on common land will have to be promoted to provide sound environmental support to agriculture.

4.69 The "Farmers' Group" as a development unit is needed in the future. Farmers as individuals cannot gain the needed competitive edge to reap the benefits of scale economies. We need to define farmers' group as a development unit for certain activities like developing land and water resources and restoration of natural resource base of the community; we also need to strengthen the bargaining powers of farmers in marketing and technology transfer. Promotion of agricultural/horticultural/fish processing centers for a cluster of villages by providing policy support to private entrepreneurs and tie up with farmers through contract production could sharpen the role of the farmer's group in development process. This could be the basis for ventilating the concept of decentralized production, with organized processing and marketing.

4.70 New Provisions for the Agreement on Agriculture have become critical for the survival of profitable farming in India. Tariffs and exchange rate adjustments are necessary but may only be short-run palliatives. The real solution for meeting competitive challenges is to promote efficiency in agriculture. Efficiency gains through domestic market reforms are also substantial. The issue of price volatility and its influence on our agricultural prospects also needs careful analysis. Detailed market intelligence and quick government response to threats and opportunities of WTO are a must to achieve benefits from WTO. Added to this is the need for articulating the inclusion of new provisions (like Development or Livelihood Security Box) as instruments in AOA. This would be crucial to allow a sufficient period to prepare Indian farmers to compete in the international market, develop on farm facilities, and develop off-farm infrastructure support.

4.71 In this context it might be noted that that there is sufficient expertise within the Agricultural Universities and ICAR institutes to do competent cost of production and farm business analysis, which must form a critical component of any SWOT analysis for Indian agriculture. However, for this to lead to a proper system, there must be closer interaction of research within the ICAR proper with that of other institutions, including economists in the UGC system, which has more experience with issues like international trade, risk management, and environmental impact analysis. The role of IFPRI in capacity building and undertaking policy research trough partnership with institutions under NARS and outside NARS in these areas assumes special significance.

### *Past Collaboration and Achievements*

4.72 The International Food Policy Research Institute (IFPRI) was established in 1975 to identify and analyze alternative national and international strategies and policies for meeting food needs of the developing world on a sustainable basis, with particular emphasis on low-income countries and on the poorer groups in those countries. The institute's research program reflects worldwide collaboration with governments and private and public institutions interested in increasing food production and improving the equity of its distribution. Research results are disseminated to policy makers, opinion formers, administrators, policy analysts, researchers, and others concerned with national and international food and agricultural policy.

4.73 Since its inception in 1975, IFPRI has contributed to Indian agricultural development through its research and policy advice. In the late 1970s, IFPRI's collaborative research in India focused on understanding the impact of food subsidies on food consumption and nutrition and income distribution. Studies were also conducted on production instability in Indian agriculture, policy modeling of food grain markets, and analysis of structural changes in the agricultural economy and implementation of growth and equity policies in the agricultural sector. Indian planners and policy makers benefited from extensive use of the results and recommendations made by these studies in formulating agricultural policies and programs.

4.74 In the 1980s, IFPRI collaborated with a number of key institutions under NARS in India to generate information on renewed agricultural and livestock development strategies. Research conducted by Tamil Nadu Agricultural University (TNAU) with primary data collected from the North Arcot district in Tamil Nadu resulted in an internationally acclaimed publication entitled "Green Revolution Reconsidered — the Impact of High Yielding Rice Varieties in South India." The research highlighted the importance of documenting both the direct and indirect benefits of Green Revolution technologies and demonstrated that, in addition to increasing aggregate agricultural production, the new technologies contributed to increases in income, employment, and the quality of diet of rural households. These results further provided support for increasing investment in agricultural research as a tool for reducing food insecurity and malnutrition in India.

4.75 More recently, in the 1990's, IFPRI collaborated with institutions of the Indian Council of Agricultural Research and several State Agricultural Universities (SAUs) including Tamil Nadu Agricultural University. Five thematic areas were identified for intensive policy research: (i) determinants of agricultural growth; (ii) institutions for agricultural development; (iii) input supply systems; (iv) irrigation investment and water management; and (v) provision of rural infrastructure. Research was undertaken through 40 individual research studies in collaboration with 50 collaborating researchers in India. Five books were published based on the outcome of this program. The Indian Planning Commission has made use of the results from these studies in formulating the IX Five Year Plan.

4.76 IFPRI continues to collaborate with Indian Council of Agricultural Research on issues related to 2020 Vision for Indian Agriculture, watershed development, and stagnation of Indian agricultural growth. IFPRI's joint research with Indian institutions resulted in more than 200 Indian scientists' visiting IFPRI in the past 25 years and benefited from joint research projects. The benefits have also accrued through organization of several workshops and seminars and through joint publications.

4.77 Some of the important conclusions of the recent past collaborative work are:

- Benefits from economic reforms and globalization of the Indian agriculture, a major reform in supply side factors — technology, fertilizer, irrigation, infrastructure, and credit is needed.
- A reorientation of the agricultural research system is required to improve client relevance of research and evolve location-specific technologies, upgrade the extension system, and set right priorities for research.
- Investments in public irrigation, which have been declining, need to be raised. Drastic institutional reform in the canal irrigation system is needed. In the case of ground water, volumetric pricing of electricity is required.

4.78 In the case of fertilizers, policies geared toward wider distribution would bring better results. Subsidies need to be gradually brought down.

- Development of rural infrastructure is critical to ensure that the farmers get their inputs in time and in adequate quantities, at lowest possible prices, and get the highest possible share in prices paid by consumers. Similarly, low-cost housing, public sanitation, supply of electricity, and water in rural areas are needed as part of an investment system integrated with employment generation and poverty alleviation programs.
- Repayment performance of agricultural credit need to be improved, interest rate subsidy brought down/withdrawn, and supplies of agricultural credit augmented.
- Provide safety nets to weaker sections in rural areas by targeting distribution of foodgrains to those who are genuinely needy has to be a part of any strategy of food and agricultural development.
- Development strategies should be tailored to local agroclimatic conditions and social and economic conditions should determine the type of development pathway.
- Policy reforms are needed to look out for the interests of farmers that would raise productivity, increase efficiency of marketing and processing, and help farmers diversify into more profitable crops.
- There is a need to experiment with new innovative institutional arrangement with greater flexibility to change through mid-course, along with on-going monitoring and evaluation efforts that encourage feed back.

### *Future Directions of Collaboration*

4.79 Keeping in mind the future challenges and opportunities of Indian agriculture, as articulated earlier in this document, current ICAR-IFPRI work plan (outlined below) aims at increased understanding of conceptual and empirical aspects of certain priority policy issues to promote sustainable agricultural development.

- Evaluation of agricultural research and impact assessment.
- Intellectual property rights policy in agricultural R&D.
- Impact of agricultural research on poverty reduction in India.
- Water resource policies.
- Training and capacity strengthening in agricultural policy research.

4.80 Capacity building through IFPRI has largely happened through a good number of Indian scientists spending varying periods at IFPRI working with the scientists at the place. Scientists from institutions other than those directly within the ICAR system have also benefited from stints at IFPRI. But, such capacity-building cases were identified by IFPRI according to the needs of projects being pursued by them, not on the basis of articulated needs of the NARS. In view of poor capacity of agricultural economists in the Indian NARS, particularly in policy research, this should be given priority by IFPRI in future. However, there is some renewed interest towards strengthening these needs now.

**CIMMYT, Mexico**

4.81 The agricultural research partnership between India and CIMMYT is one of the world's most productive and beneficial research arrangements. The arrangement is driven by the common objective to promote and accelerate the progress of research and training in the development and dissemination of improved maize and wheat systems. The arrangement is to pursue research based on the exchange of seed and plant breeding materials, scientific information and methods, and research expertise. The partnership is also intended to promote research collaboration throughout South Asia.

4.82 Strengthening in the relationship between ICAR and CIMMYT was marked by the signing of the first formal work plan between the two institutions covering 1989-1991 and thereafter continuously. Some of the major benefits of the earlier partnership include: i) exchange of useful germplasm for development of hybrid varieties, besides incorporating tolerance to biotic and abiotic stresses, ii) development of maize genotypes tolerant to turcicum leaf blight and dummy mildew, iii) availability of upgraded sources for quality protein programs, and iv) human resource development in terms of advanced training in CIMMYT's area of competence vis-à-vis crop improvement, development of research skills, etc., keeping in view emerging challenges, the current focus of partnership include improving genotypes with tolerance to abiotic stresses such as excess water and drought, forecasting and tackling the diseases of banded leaf and sheath blight, post-flowering stalk rot, in-bred line development for effectively tackling the pest menace particularly stem borers through the use of frontier technologies in addition to commercial technology, marker assisted selection, the use of genetic engineering to improve tolerance to biotic and abiotic stress, etc.

***Impacts from India and CIMMYT***

4.83 The international exchange of maize and wheat seed between the breeding programs of CIMMYT and India has been extremely active over the past 40 years. In the most recent decade, from 1990 to 2000, CIMMYT distributed 668 international maize trials to breeders in India. Over the same period, CIMMYT sent Indian breeding programs 873 international wheat nurseries with seed of bread wheat, durum wheat, triticale, and barley. These figures do not include hundreds of separate requests from individual breeders in India for seed from CIMMYT.

4.84 Collaboration in plant breeding has had good results in farmers' fields. In 1990, commercial open-pollinated maize varieties produced in collaboration with CIMMYT were grown on 1.15 million hectares in India. These figures are conservative estimates and will have to be updated. Indian researchers recently estimated that 35 percent of India's maize area is planted to improved maize; of this, 25 percent contains CIMMYT germplasm.

4.85 As for wheat, preliminary data indicate that, of the 184 commercial semi-dwarf wheat varieties released by India between 1966 and 1997,152 were either CIMMYT crosses or had one CIMMYT parent. The most widely grown wheat variety in India today is PBW-343, a cross originating from the CIMMYT wheat breeding program.

4.86 Just as CIMMYT researchers who have lived in or visited South Asia have gained from interacting with their colleagues in India, many Indian researchers have benefited from professional development opportunities at CIMMYT. Since 1966, more than 500 agricultural scientists have participated in workshops, intensive courses of study, and special short-term research projects.

### *Continuing Results*

4.87 Several recent innovations attest to the continuing originality and vitality of the India-CIMMYT research partnership. They are the latest in a long series of technologies that have made both India and CIMMYT points of reference for agricultural research worldwide.

4.88 Quality protein maize (QPM) looks and tastes like normal maize but has a better balance of essential amino acids, giving it a nutritive value approaching that of the protein in skim milk. The protein value of QPM was identified in the 1970s, but much difficult research had to be done to make this maize a competitive alternative in farmers' fields; only CIMMYT persisted and succeeded in this undertaking. This achievement won recognition in 2000 when Surinder K. Vasal, long-time CIMMYT researcher from India, shared the World Food Prize with Evangelina Villegas, another CIMMYT scientist. Interest in QPM has spread throughout the world and India is one of the countries developing QPM varieties.

4.89 The CIMMYT-related wheat variety PBW-343, mentioned earlier, is capable of yielding 10-15 percent more grain than any other variety previously bred in India. PBW-343 has been recommended for cultivation throughout the country and now covers more than 4-5 million hectares (about 25 million hectares are sown to wheat in India), extending from the northwest to the northeast.

4.90 There is also evidence that wheat genetic diversity is increasing in farmers' fields. Through the international exchange of wheat germplasm and by making greater numbers of crosses between diverse parents, breeders have incorporated more diversity into the individual varieties they develop. Most of the recent successful crosses have been derived from crosses between Indian and foreign cultivars. Farmers also grow many more of these genetically diverse wheat varieties. The most popular varieties, such as PBW-343 and WH542 are now planted over as extensive an area as the most popular wheats in previous decades.

4.91 Fourteen commercial often-pollinated maize varieties released by India during the past 25 years have been produced in collaboration with CIMMYT. In 1990, these varieties were grown on 1.5 million hectares in India. Further, maize products from CIMMYT's subtropical sub program have performed exceptionally well in traits in India and China and are being used extensively in breeding programs.

### *Indian Researchers and CIMMYT*

4.92 Over the years, many distinguished Indian scientists have contributed to CIMMYT's research program and management through their participation on CIMMYT's Board of Trustees. Several of CIMMYT's most experienced senior research staff are from India. Sanjaya Rajaram, currently the Director of the Wheat Program, recently received the prestigious Padma Shri Award, given by the President of India, for his outstanding contributions to Indian agriculture. He has long been recognized as one of the world's premier wheat breeders. Shivaji Pandey, Director of the Maize Program, also has many years of experience and recognition as a research director and breeder. He has received awards from five countries in Latin America for his contributions to maize production and is an editor of *Crop Science*. Prabhu Pingali, Director of the Economics Program, has many distinguished accomplishments to his credit; in 2000, he was elected President of the International Association of Agricultural Economists. In working at CIMMYT, these and other Indian nationals have contributed more than 160 person-years to the cause of developing country agriculture.

### *Rice-Wheat Consortium*

4.93 Researchers began to document and investigate problems with resource degradation in rice-wheat (R-W) areas about 10 years ago. In the first phase (late 1980s to the early 1990s), researchers initiated diagnostic studies at selected sites and developed a regional management structure (RWC) that included national research programs, IRRI, and CIMMYT. The second phase of work starting in 1994 gave this work a more formal framework by establishing the NARS driven Rice-Wheat Consortium for the Indo-Gangetic Plains (RWC), now one of the CGIAR's System-wide programs. Strong emphasis was given to regional research management by RWC members, who currently include staff members from the national programs of Bangladesh, India, Nepal, and Pakistan; staff from CIMMYT (the convening Center) and IRRI, IWMI, ICRISAT), researchers from a range of universities and ARIs (e.g., Cornell University and Michigan State University), and representatives of the development community. China is an associate member of the RWC.

4.94 Research priorities are set by a steering committee. The RWC focuses on four research themes: tillage and crop establishment, integrated nutrient management, integrated water management, and system ecology/ integrated pest management. Crop improvement research, socioeconomics, and policy analysis are treated as overarching issues that affect all four research themes.

4.95 The 1997-1998 wheat season in the Indo-Gangetic Plains marked a turning point in R-W research. There was an interest in reduced tillage and establishment methods, ranging from farmers engaged in participatory research up to heads of extension and ministries of agriculture. It is significant to note that the new tillage alternatives for wheat have made it possible to sow 5-25 days earlier, raise yields by 0.5-2.0 t/ha, and reduce cash and labor costs by half. In some areas these practices may also make it possible for farmers to grow a third, high-value crop after wheat and before rice, where previously none could be grown. Some advances have also been made in understanding interactions in the cropping system such as the implications of changes in tillage and crop establishment practices for nutrient management, weed management, and rice and wheat germplasm requirements. Researchers from Haryana Agricultural University India report that zero-tillage is used to grow wheat on hundreds of thousands of hectares, and the State Department has included this tillage practice in its recommendations for farmers. The practice has helped wheat farmers to control the weed Phalaris minor, a serious problem. Demand for zero-tillage drills is so high that local manufacturers must work hard to meet it.

4.96 Scientists at Haryana Agricultural University have observed that wheat yields in areas affected by Phalaris rose to 4.35 t/ha in 1999-2000 compared to 3.45 t/ha in 1994-1995 and 1995-1996. Reduced tillage has several potential environmental benefits, including improved water use efficiency and conservation (important as water becomes scarce), reduced need for herbicides, erosion control, reduced nitrogen losses into the environment, and improvements in soil structure. Possibility of greater carbon sequestration is expected to help build soil physical health and lessen the contribution to the atmospheric load of global-warming carbon dioxide.

4.97 Further, bed planting, a technique developed by farmers in northwestern Mexico and adapted and tested by CIMMYT researchers, offers farmers a more environmentally sound option for conserving water, fertilizer, and other inputs as well as controlling weeds. According to recent information from ICAR, farmers in many villages in Punjab and Haryana have left off sowing wheat on the flat and are using bed planting. Advantages cited by ICAR include a 40-50 percent lower seed rate, 30-40 percent water savings, higher yields, less lodging, and reduced herbicide use through mechanical weeding, among other advantages. Farmers can potentially save on inputs and engage in more environmentally suitable agricultural practices.

4.98 The next phase of RWC research will have to focus on the new paradigm of the systems approach, with interdisciplinary teamwork for greater impact. It is to be noted that CIMMYT, RWC, and the Indian scientists assisted in the local manufacture of equipment for O-tillage and bed planting and made them available to farmers for testing. Indian scientists also participated in roving seminars organized by the RWC and visited programs in neighboring countries.

4.99 However, it should be noted that funding for inter-Center activities like RWC is not provided as per the need. IARCs are caught up with financing new start-up activities as well as costs of completing long-term strategic research. Some IARCs are reported to have diverted funding to these new start ups, adversely affecting long-term ongoing activities.

# 5. Effectiveness of the CGIAR

5.1 Launching of international agricultural research Centers was primarily done to address the chronic problems of food shortages faced by several developing countries. The major research mandate given initially to these Centers was to develop technologies capable of raising productivity of primary food grain cereals. IARCs have succeeded in this mission. However, over time, issues of sustainable use of natural resources and poverty alleviation have become more dominant. Simultaneously, future effectiveness of IARCs has to be measured against the existing and emerging funding difficulties.

**Research Programs — Sustainable Land Use Is Priority Number One**

5.2 IARCs, specifically CIMMYT and IRRI, no doubt, have played a pivotal role in wiping out the scourge of food shortages not only from India but from several other developing countries also. CGIAR's contributions emanate from the support it provides to research and related activities under the six broad program thrusts (Anderson and Dalrymple, 1999): (1) research to increase productivity of resources committed to farmers' food production; (2) management of natural resources; (3) improvement of the policy environment by assisting countries in formulating and implementing food, agriculture, and research policies; (4) capacity building by training and strengthening national agricultural research systems; (5) germplasm conservation by collecting and classifying genetic resources and maintaining gene banks and other means of conservation; and (6) building linkages between institutions in national systems and other components of global research systems.

5.3 These programs and activities leading to substantial growth in productivity were centered broadly around development of high-yielding varieties, particularly of rice and wheat. With provision of fertilizers and irrigation water, high yielding varieties fueled the Green Revolution in India and elsewhere in South Asia. Rising population (~ 16 million people/annum), however, continues to put severe strain on agricultural productivity. The demand for additional food — (3 to 4 million tons/annum) can only be met by increasing productivity. This is foreseen because most land suitable for cultivation has already reached the point of horizontal limit and any further expansion is likely to be opposed by natural and economic constraints (Katyal, 2001).

5.4 Hence, more than HYVs, sustaining forward and upward movement in productivity necessitates improvements in other crop management practices. Many of these practices call for further intensification of input use and greater strain on static land resources, leading to rising land degradation and pollution of the environment. Already 199 mha (million hectare) out of 329 mha geographical area are affected by degradation of one or the other kind (Sehgal and Abrol, 1994). The result is declining pattern of productivity growth during the 1990s (2.14 percent/year) compared to the 1980s (2.97 percent/yr). The scenario is more worrisome, since it is occurring against the background of increasing rate in spread of HYVs (37 mha/yr vs. 32 mha/yr), intensity of fertilizer use (76.0 kg/ha/yr vs. 46.5 kg/ha/year) and growth in irrigation (1.50 mha/yr vs. 1.23 mha/yr) (Katyal, 2001) — the three basic elements that triggered the Green Revolution.

5.5 Obviously, the concern is sustaining productivity growth, which balances the rising food needs of a burgeoning population and retains farming as an economically satisfying enterprise. The situation is complex because farms are small, while the population dependent on farms for employment is large. In India, four out of five cultivators (total number 106.6 million) are small and marginal land holders (area owned < 2 ha), and as per the 1991 census, for 59 percent (35 percent land holders, 24 percent landless workers) of the India's work force, agriculture remains the prime source of employment (GOI, 2000). Furthermore, on 65 percent of the arable area (~ 142 mha), agriculture is rainfed. Cereal-based farming alone does not seem to be a solution, at least in unirrigated areas, to create more jobs or, for that matter, to alleviate poverty and hunger, which remain a typical phenomenon of rural India. Even in irrigated areas, too much intensification and too little concern about holistic management solutions necessitates diversification of land use with soil rejuvenating practices.

5.6 Future agriculture research will have to integrate high productivity growth with economic viability that satisfies the farmer and his animal support system. Simultaneously, it includes curative actions for and diversification preserving the quality of land and preventive actions against its degradation. In essence, agricultural research must lead to a total rural development — the key elements of which have been enunciated in the current rural development strategy of the World Bank. These are: reduction of poverty and hunger, fostering growth in productivity, sustaining quality of natural resources, and ameliorating natural resource degradation (Anderson and Dalrymple, 1998). In fact, these are the very goals that India has reaffirmed and pursues through her National Policy on Agriculture.

**Economic Efficiency and Effectiveness — New Mantras of Research Programs**

5.7 The latest change design and management initiative undertaken by the CGIAR at the International Centers Week (ICW, 2000) and the mission statement emanating from it supported widely shared rural sector development components through its research and research-related activities. The latest mission statement adopted by the CGIAR at its 2000 Mid-Term Meeting reads as follows:

5.8 “To achieve sustainable food security and reduce poverty in developing countries through scientific research and research related activities in the fields of agriculture, forestry, fisheries, policy, and environment.”

5.9 Contained in this mission statement is the message on evolution of new programs and renewal of the System. What started as production research on basic food crops has to move to a system focus on sustainable use of natural resources, specifically forestry, water management, and aquatic resources. Although issues on sustainable food security and reducing poverty commonly afflict the developing world, their solutions defy common prescriptions across developing nations. The deliverables of global public goods research must influence the well being (defined as ability to survive and grow in quality of life) of local communities. This goal is possible to reach, provided local perceptions, needs, and capabilities are intertwined with the global research agenda. This calls for a shared vision, broader effort, and joint action among IARCs and between IARCs and national agricultural research systems. Apart from synergy of output, working in teams is more cost effective.

5.10 Economic efficiency is a must, since CGIAR must respond to a series of funding difficulties. Due to stagnating and possibly decreasing investments in the future (an exit option is being promoted by the World Bank), it is necessary to consolidate and improve the relevance and effectiveness of the research agenda and reform structure and governance to enhance internal efficiency and attract a wide variety of potential donors to stabilize long-term financing. Moving initiatives for program change forward and resource generation from hitherto non-conventional sources upward was the basic terms of reference given to Change Design and Management Team (CMDT), set up following ICW 2000.

**Research Programs — New Format**

5.11 The most immediate research activity-related change (termed also as the first order change) recommended by the CMDT is the adoption of the programmatic approach. It means aggregation of many individual research efforts into joint focused programs with greater emphasis on strategic opportunities. Although an extension of the existing format, it also entails clear demarcations between global (say, land degradation mediated climate change), regional (erosion mediated land degradation), and sub-regional/national (improved land and water management to control erosion) programs. In this mode, it becomes necessary to foster ties among (1) IARCs for global programs, (2) IARCs and regional forums for regional programs, and (3) and IARC and specific country NARS for location-specific, in-country programs.

**CGIAR Reviews — Too Frequent**

5.12 It is genuinely opined that CGIAR, not withstanding its excellent track record, is resorting to too many reviews and frequent restructuring than required. It is not even giving time to test the worth of restructuring that has already been tried. Change is good as long as it brings change for the better. This type of frequent review and restructuring needs to be minimized, if cannot be avoided, for sometime. Such reviews may become necessary once in 10 years.

5.13 For instance, ICRISAT faced crisis of funding and went into downsizing, restructuring, and reengineering several times. ICRISAT, after one of its recent review and restructurings, decided that there is an urgent need for staff members to feel secure and concentrate on development research in 1999 rather than worry about another downsizing. The white paper prepared on the topic assured that 1999 will be a year to "stay, fight, and grow" rather than "shrink, fight, and adjust." The elements of the strategy included program- and location-based changes, people-based adjustments, cost saving and revenue generation initiatives, and efficiency and effectiveness review. But again in 2001, there was yet another downsizing exercise. This has added to the uncertainty and will definitely affect institution growth and sustenance of quality of research output.

5.14 Again, for instance, global challenge programs (GCPs) are to substitute System-wide programs in search for more focus. System-wide programs did not possibly succeed because they were based on collaborative principles, resources were not earmarked, and governance failed. Though GCPs are based on competition and resources are clearly available and earmarked (with much interest from non-formal or normal donors, expected to enhance science, expertise, and funding), their implementation depends on the cooperation and joint work of multiple project partners. There is a suggested governance mechanism whose costs may also become a burden to the program, apart from uncertainties concerning of the usefulness of its intended role. Cost effectiveness remains an overriding concern, along with risk of successful implementation.

5.15 Since a decision is already taken to launch global challenge programs, we feel that global challenge programs have to be formulated on the basis of regional challenge programs. Selection of GCPs, therefore, need to be done in full consultation with GFAR, regional forums like ARAARI, etc., and other stakeholders. Similarly, beneficiary NARS should have the say in not only selection of issues but also Centers. As otherwise to retain dominance, there may be scope for unhealthy lobbying for such projects by big and powerful Centers. Prudence urges that the Centers should no doubt compete with each other for GCPs — but only to an extent, under the broad vision of CGIAR and guided by the corporate identify of CGIAR. At all levels, institutional bias may have to be avoided.

5.16 Similarly, we do not clearly perceive the reasoning behind the decision regarding establishment of a Science Council (SC) in place of Technical Advisory Committee (TAC). If TAC required change, it would have been effected as per need and appropriateness. The question is: Who prevented this from happening? Now a separate task force is suggested to work out the details and modalities of change of TAC to SC. All these will add to institutional proliferation and avoidable costs, send the wrong signals, and erode confidence in a meticulously built system that has delivered.

5.17 The cost effectiveness of IARCs vis-à-vis other alternatives, including NARS, may become a decisive criteria for donors in future. But the issue is not IARCs or other alternatives, but rather a combination of them, since each has its own comparative advantage, niche, and constituency. We do not foresee any system other than IARCs that can substitute for bringing international experience to the benefit of the national system.

**Research Programs — From Collaboration to Partnership**

5.18 Within the joint-research arrangements that were in practice till recently in India, ICRISAT scientists (and, for that matter, scientists from other CG Centers) drew up a program outline and presented it to NARS scientists for collaboration. ICRISAT also provided necessary funding support to conduct the experiment/study. Generally, the NARS scientists remained passive recipients and seldom suggested significant modifications. They also followed procedural guidelines and used experimental material as directed. Consequently, these programs remained ICRISAT programs, with NARS treating them as a routine activity. The usefulness of this working arrangement was apparently underutilized, particularly with regard to capacity building.

5.19 This deficiency has now been removed and as per the recent working arrangements, NARS scientists are involved right at the entry point when a problem is defined, the solution-finding concept developed, and the program outline prepared. The role of ICRISAT, which was coaching/directive, has changed to that of a facilitator. This shift from collaborator to partner is the model that an IARC should evolve when it runs joint programs with developing country NARS. We were told at ICRISAT that this format first attracted and then ensured greater involvement and commitment from NARS. We believe participative arrangement will encourage NARS to invest their own resources in joint research. We also foresee faster capacity building of NARS scientists. Either way, it is a healthy step toward lessening financial burden on and increasing effectiveness of IARC programs. Effecting economy in the use of financial resources is a crying need in the times of fiscal crunch.

**Funding — Introduce Economy Measures and Widen the Net**

5.20 During the last decade, funding of CGIAR programs has grown modestly at an annual rate of 1.8 percent, rising from U.S. $290 million in 1990 to U.S. $340 million in 1999 (0.9

percent in real terms). The CGIAR's Finance Committee expects this trend may continue up to 2010 that is a modest nominal growth (2 percent p.a.) but close to zero growth in real terms. Its assessment is predicted on assumptions of no change in ODA funding and overall growth of U.S $60 million by 2010, resulting from a doubling of investments by developing country members and new support from non-CGIAR sources such as the private sector. This implies a CGIAR budget of approximately U.S. $400 million (in nominal dollars) by 2020. Finally, the CGIAR's resources have gradually shifted from a more unrestricted to restricted nature. At the System-level, unrestricted funding fell from 68 percent of the total in 1990 to 53 percent in 1999-2000. Thus, the System's capacity to continue to focus on IPG may become increasingly problematic owing to the growing share of restricted funding. With growth predicted to remain flat in real terms with ODA support insecure, there is a need at minimum to target the System's resources more efficiently and effectively within the current framework for priority setting. Alternatively, there may be need to adjust the framework itself.

5.21 CMDT has made several specific recommendations on stabilizing the financial health of the CGIAR. Broadly these can be classified as follows: (1) widening the financial net, and (2) introducing some economy measures. Garnering more support from NARS and private sector is among several suggestions on enhancing donor portfolio. So far the contribution from NARS has not been very significant. Furthermore, if past trends on financial contributions are any indication, chances of rise in direct financial support from developing country NARS do not look very bright. Instead their support in-kind — i.e., human resource, extension of in-kind services, and land and other facilities — may be forthcoming if tied up with tangible returns. Agreement with NARS on sharing the costs of programs of common interest, as noted earlier, is one such option.

**Indian NARS**

5.22 Further, we are of the opinion that the excellent human resources that are available, typically with Indian and some other developing country NARS, can substitute substantially for direct financial support being envisaged by CMDT. Even current IARCs hire NARS scientists as visiting scientists for short-term need-based assignments (to fill in for positions of scientists on sabbatical or to undertake specialist tasks). ICRISAT has plans to attract more deputations to fill short-term positions in response to urgent assignments. No doubt, the existing arrangement helps the IARCs to reach program goals in a very cost-effective way and assists NARS scientists in gaining the exclusive experience of working on a sharply focused program in the work environment of an IARC. However, the scope of in-vogue, short-measure visiting scientist schemes can be enhanced by replacing it with a more regular scheme of specific program- or job-based secondments of suitable in-service NARS scientists/technicians.

5.23 In the proposed arrangement, an IARC decides on the regular number of essential scientist/technician force it will maintain, while the rest are filled through secondments. This scheme will necessitate some new adjustments in the prevalent structural and organizational setup and employment policies of IARCs and a more flexible outlook on the part of the NARS to second their scientists to work on fixed-term basis. The scheme is as follows:

- IARCs work in a program mode.

- Its research portfolio consists of GCPs (Global Challenge Programs) and carefully selected programs in which a particular IARC enjoys distinct advantage over national capabilities and facilities.
- Individuals who are known world leaders in the field of their specialization head these programs (Program Leaders).

5.24 Support scientists/technicians come largely from NARS. They will already be employed and are deputed to work with the Program Leaders. When on secondment to an IARC, these scientists continue to draw their salary and other benefits from their employers. However, an IARC pays for their dislocation/relocation costs, a deputation allowance (not to exceed 50 percent of the salary), a suitable residence or a house rent allowance in lieu of that, and medical and other benefits as per entitlement and in accordance with the extant rules of the NARS. The deputation will last for a pre-decided period, but not exceeding five years. With this arrangement, the cost on nationally and internationally recruited staff is expected to fall significantly.

5.25 Besides, NARS scientists will have wide open opportunities to build their professional capacity by working with the Science Leaders. They also stand to gain by imbibing the work culture ethos of an IARC. On both counts, these scientists/technicians will expectedly contribute more both in quality and quantity when they return to their parent institute. This arrangement is going to be highly cost-effective from CGIAR point of view, because the investments on national and more particularly internationally recruited staff will fall down significantly. Currently, the major part of an IARC budget –60 percent — goes to meeting the costs of salaries and benefits. We also visualize that this arrangement will enhance national capacity and capability and add value, relevance, and applicability to scientific research output.

5.26 Another principle that will be helpful for IARCs in this context includes repositioning organizations to provide knowledge services in addition to the supply of products. Organizations selling niche knowledge services will always be in demand and will be sustainable. It is difficult for organizations to survive competition if they are positioned to sell only products. Thus formal and informal arrangements with NARS and other stakeholders in generating and selling knowledge services should also be emphasized in IARCs in the future to achieve a surge in impact.

**Private Sector**

5.27 In the total global research funding on agricultural R & D, the contribution of CGIAR is only 5 percent. The rest is through public sector, private sector, and other sources. In this context, tapping private sector, besides NARS, assumes significance. They are considered partners in progress.

5.28 Support from the private sector remains generally an untapped resource to augment finances of CGIAR. The conflict of interest that a private sector (profit motive) pursues and a public sector (delivering general public goods free) is committed to is the basis of a general reluctance to approach this source freely. Alliances could be forged if the private contribution does not insist on exclusive rights on research outcomes. Instead, it allows general distribution of spill-over benefits (including the donor) free of cost. ICRISAT has developed a model on these lines.

5.29 ICRISAT began working with nine private sector units. Now it has in its fold 15 private sector firms that are each contributing U.S. $5,000 a year for funding biotechnology and molecular breeding research at ICRISAT. The contributions from private sector engaged in the development of downy mildew resistant pearl millet lines are used to develop initial breeding material, which is then accessible to both private donors and public institutions at no cost. With this arrangement, the public mandate of ICRISAT is served with private funding. Not only that, savings from the private donations have been gainfully employed to enlarge the size and scope of downy mildew resistance research.

5.30 NARS are also benefited as they get more technologies quickly. Since the private sector is more business oriented and close to the farmers, it provides real feedback for needed improvement of traits by ICRISAT research. Such a partnership has helped private sector to supply better and more relevant technologies, timely availability, and diversity of materials at lower price on account of competition. However, the general tendency of the private sector to exploit the poor needs to be monitored and checked.

**Project-Related Funding**

5.31 Over the years, though the core budget has stagnated or fallen, unrestricted or project-based funding has increased sharply. Generally, the IARC scientists make applications for funding individually. At times, NARS scientists are also partners in this research. Joint (NARS and IARC) funding applications for projects that aim to reach common goals — typically with those agencies that insist on involvement in developing country NARS — is seen as enlarging the funding portfolio of IARCs. Working together will also enhance the visibility of an IARC's contribution in regional- and site-specific research programs and the capability of NARS to undertake such research.

5.32 National scientists working in an IARC individually or jointly with other NARS scientists can apply for research funding to in-country science departments and trusts. Though they have potential, these funding resources have remained largely untapped. In India, public organizations like ICAR, Department of Science and Technology, and Department of Biotechnology, and private trusts like Tata, MAHYCO, etc., are among the prominent funding agencies that support scientific research.

**Global Information Exchange**

5.33 ICRISAT is also involved in global information exchange with NARS that is proving to be very useful. It is involved in supporting in-country research and execution in some countries. In fact, in many cases, it has been instrumental in reducing research lag by four to five years, thereby contributing to an increased availability of improved technologies in the NARS. IARCs can consider setting up a repository of information and developing quick methods to disseminate it. NARS can draw benefits from lessons from such set ups. We realize that, although technologies are available to benefit from change, change has eluded us in the past and continues to elude us in the present. Strengthening the dissemination of knowledge is a priority program that IARCs and NARS should develop together.

## Comprehensive HRD Program

5.34 Capacity building, networking, and short-term training are critical for NARS and it should be jointly done on a partnership basis. In this, even short-term, non-degree programs, travel seminars, and degree programs involving just a few months' stay by NARS scientists or students at IARCs as part of thesis work may be options. Networking of advanced research centers (Gongs) with IARCs — NARS is very important. In the case of India, they may organize advanced training programs for NARS scientists in cutting-edge areas, even hiring resource persons from abroad. This is not only cost effective but also obviates the difficulty of sending Indian scientists abroad for such training.

## Reflections on NRM Research as a Global Public Good

5.35 The opinion is mixed. While the methodologies and processes may have global public good (GPG) content, their application needs extensive modifications to suit to local situations. While the role of NARS-led initiatives is gaining greater currency, their impact is not tangible in the short run, although substantial in the long run. Their replicability and continuity is again uncertain, as they heavily depend upon local group or community action. With due consideration for their importance, they are now being factored into the design of research projects, including watershed projects, at ICRISAT. There may be a need to search for social stimulants to achieve the sustainability and replicability of NRM efforts. This recommendation is based on the fact that the viability of watershed programs fades away as soon as the benefactor leaves the beneficiary. Another important factor relates to the size of benefit. If it is small — say, 10 to 15 percent — then the probability of adoption is considerably reduced. It should be noted that NRM research / entails higher recurring costs compared to crop technology, which may serve to deter farmer to adopt NRM technologies. Further, they are also management and input intensive than more of science based interfacing scientific efforts with development department initiatives is an imperative that needs to be pursued vigorously.***what does this mean?*** Therefore, success in NRM technologies is observed to be less than expected and also uncertain.

5.36 In case of NRM research, ICRISAT has taken a right view to act as a facilitator and neutral organization to exchange global experience and bring all the actors together — local people and their organizations, research institutions, agricultural universities, district administration, NGOs, and policy makers — to act on a common agreed work plan, pooling their resources and knowledge. Earlier, these actors were working independently in the same watershed without success, but now they are working together with synergy. There is a country co-coordinator from the NARS, who is coordinating the activities of all actors to achieve the targets of the joint work plan. The initial results of the new approach are reported to be promising and ICRISAT wants to build on this valuable experience while going for upscaling.

## Reflections on Science vs. Poverty Focus in CGIAR Agenda

5.37 Emphasis on both science and poverty is needed. We have to learn to convert increased food production to livelihood prosperity. Both need to be pursued by working together with NARS. The role of strengthening social sciences in the CG/NARS System thus assumes significance in understanding the socio-economic and policy environment. But it is now seen that the Centers are being stretched too thin and not enough time is available to Center scientists to publish their results in peer-reviewed journals, take sabbaticals, and rebuild their human capital. This trend needs careful review.

5.38 The impact of research findings typically on poverty alleviation should preferably be conducted by independent individuals/bodies. Such studies will have greater creditability than within-institution evaluations.

# 6. Conclusions and Suggestions

## Conclusions

6.1 It should be noted at the outset that CGIAR Centers have made significant contributions to Indian agriculture. Although not many rigorous impact studies are available, it is widely acknowledged that the CGIAR varieties have been an important contribution and should be continued. The impact was substantial because of the strength of the national system.

6.2 A number of developing countries already consider India ahead in terms of trained manpower, techniques, and technologies; Indian NARS can offer manpower and contribute jointly with IARCs on training and technical assistance to other developing NARS in the region. This needs to be noted by IARCs working in the region.

6.3 With India, which has a stronger NARS, IARCs have to mainstream production problems into the research paradigm and provide workable models, methods, and approaches to the national system for further modification and adoption.

6.4 The gene pools of the crops held in trust by CGIAR Centers are highly valuable. Indeed, the advances in science occasioned by the biotechnology revolution, including functional genomics and transgenics, open up new and valuable opportunities to exploit these gene pools for the benefit of all crops. This could represent a major comparative advantage for CG Centers in the future. The Negotiation on International Undertaking, which will provide a multilateral system of facilitated access to plant germplasm under the auspices of the FAO — including 20 crops in CGIAR Center gene bank– is welcome.

6.5 In South Asia, where rural poverty is closely associated with near or complete landlessness, farm and non-farm employment, crafts, trades, and transfers are the primary sources of income. Crop and livestock incomes are more important sources for the less poor. CG Centers therefore need to address the entire life support system of the poor through agricultural research interventions.

6.6 Exciting developments in science such as biotechnology and information technology have the potential to greatly reduce research and adoption lags. CG Centers have to heavily invest in these in the future. But promoting transgenics in developing countries needs to be avoided by CG Centers, as it involves sensitivities.

6.7 There are still questions as to the degree to which natural resource management research on such topics is location-specific and whether it has sufficient international public goods (IPG) characteristics to justify major investments by IARCs. However, there is every indication that IARCs have a comparative advantage in aspects of natural resource management research that require application of new science. These include diagnostic research to explain the dynamic functioning of natural systems, thereby facilitating the construction of system models. There is also a need for improved data and information on the extent, causes, and consequences of land degradation to support informed decision making at all levels, from the landscape to the plot.

6.8 A perennial issue for IARCs is the appropriate balance between location-specific applied/adaptive research and more basic/strategic research on constraints that are important in many countries. Emphasis on the former is justified by the need to demonstrate impact and relevance to the poor and to provide feedback for the latter. Emphasis on the latter is rationalized on the grounds that the outputs are more likely to be international public goods and hence represent both a comparative and complementary advantage for the IARCs vis-à-vis partners and alternative providers. The reality is that, on account of the emphasis on poverty alleviation, the IARCs are underfunded and overstretched; as a result, the quality of science is being threatened, as Centers are pulled downstream and compelled to oblige the pet projects of donors.

6.9 IARCs need to play many different roles depending on needs, priorities, and comparative and complementary advantage vis-à-vis other R&D actors. These roles can range from leadership, primary, catalytic, facilitative, convincing, custodial, and advocacy. The appropriate balance of effort will need to be established along the R-to-D (or discovery-to-delivery-to-impact) continuum. IARCs and regional research organizations (RROs) will need to play crucial backstopping roles for smaller/weaker NARS. A more critical role to be played by RROs is that of honest broker and effective interface between NARS, the CGIAR, and the private sector.

6.10 The uneven geographic impact of the CGIAR's work has meant that major regions having a high incidence of poverty — notably, extensive areas within South Asia and sub-Saharan Africa — have benefited much less from technological advances in agricultural productivity. The persistent and heterogeneous nature of poverty in these areas, their problematic and often degraded production potential, and the weakness of their institutions require a more integrated, multidisciplinary effort.

6.11 CGIAR should promote potential evolution to alternative sources of funds– i.e., the NARS, ARIs, and the private sector in the next 20-30 years, keeping in view the unevenness in research capacity between and within regions, weakness of incentives for private sector investment in crops of importance to the poor, and IPR constraints on access by the poor to technologies developed by the private sector. Nonetheless, in certain strategic and advanced fields of knowledge the need for the global economies of scale inherent in international agricultural research will endure. And, for certain kinds of issues — e.g., the problems of the commons — global efforts by scientific, politically neutral, and transparent entities like the CGIAR will still be required. CGIAR-type institutions and / or mechanisms will also most likely be needed to deal with the following more or less enduring concerns:

- Conservation, characterization, distribution, and stewardship of genetic resources.

- Strategic research platforms in the North and South based upon the principles of partnership.
- Training of science / information workers. The arrangements could involve NARS-sponsored and IARC-approved secondments.
- Steering / coordination of a global knowledge system for agricultural and natural resources.
- Global trends analyses and policy formulation.

**Suggestions**

6.12 The task ahead is for the CGIAR to co-opt Indian NARS as a valued partner for not only building centers of excellence but also for improving the output of other NARS. The following recommendations will provide the needed directions in this regard.

***Specific***

6.13 Indigenous germplasm knowledge/collection maintained by NARS institutions has been at the center of success of CGIAR. This should be duly acknowledged and credited at the time of making claims of contributions and its flow to NARS should be uninhibited.

6.14 Natural resource management should be the activity of NARS, not IARCs. IARCs can serve best by facilitating the working arrangements with NARS, but not getting involved in activities at farm/community level. They can provide international experience and serve as window to the outside world for experience.

6.15 IARCs should not promote transgenics in developing countries wherein the science, industry, and instrumentation involved rests with the developed world. This will lead to the development of technology that will depend on overseas knowledge to sustain food production in the developing world.

6.16 Developing countries should significantly contribute to CGIAR System and make it function as a corporate/collective holding company. They should not only be more proactive in articulating their needs, but also see that they get redressed without fail.

6.17 IARCs prefer funding weaker NARS institutes where their authority is well respected. IARCs should not apply that approach while working with stronger NARS like India's. They are also comfortable with non-audited NGOs. This may have to be reconsidered.

6.18 A mechanism should be developed to share financial resources, with the CGIAR even subcontracting some of its activities to NARS. It may prove to be very cost effective. In general, IARCs treat developed (donor) nations as partners and developing countries as "trainee" nations. This perception should go as the IARCs got global recognitions/footage from NARS. A large scope exists for the exchange of M.Sc/Ph.D. students between IARCs and NARS and placement of in-service scientists through secondments and deputations.

***General***

6.19 In view of the Asia-Pacific region harboring the highest concentration of hungry people, CGIAR should give priority attention to this region.

6.20 IARCs should give more and explicit attention to improving productivity to enhance food security rather than directly focusing on issues like environment and equity, which involve local political sensitivities.

6.21 The genetic resource conservation strategy must be devised in a way that the existing trust and faith in the CGIAR System continues while we devise systems and procedures to meet the changing paradigms that conform with international debates and developments on this subject. In the process, access to the availability of existing germplasm in the CG System should be assured while ensuring its protection from patenting by the private sector. Also a strategy should be evolved to ensure its duplication in the gene banks of some of the capable NARS. In this context, the CGIAR must play a proactive role in advising NARS on IPR-related issues and must take active part in the global debates taking place in FAO, CBD, UPOV, WTO, etc.

6.22 IARCs should become vehicles for exchange of knowledge with NARS in different parts of the globe. They should serve as repository of information, as they are the repository of germplasm. They should also bring in private enterprises to areas such as biotechnology, which is very capital intensive. They should serve as leaders in developing and guiding implementation of globally acceptable rules and procedures for sharing information.

6.23 CG Centers need to give higher priority to research relating to biotechnology as well as germplasm enhancement, addressing concerns related to both biotic and abiotic stress resistance. While some Centers are doing exceedingly well, others are yet to catch up in this regard. In the developing countries, NARS particularly look toward global public and private research centers to provide required support in this direction. Also policy decisions are needed to ensure availability of such research results to the end users freely. In this context, CG Centers could be advised to strengthen this area as a core activity in the future.

6.24 For developing a research priority-setting mechanism, the involvement of regional forums would be highly advantageous. Hence there is full justification for institutionalization of specific interface arrangements that in return would ensure greater ownership by NARS.

6.25 It has been observed that network and human resource development programs are now getting less priority, although the relevance of both activities for developing NARS is far greater today than ever before. For the benefit of NARS and the required visibility of CG Centers, germplasm and varietal testing programs are critical; they should not be lost sight of on the pretext of donor fatigue for such programs. Unfortunately, the tendency lately is to accord low priority to such activities. Joint management and devolution of some training programs, involving stronger NARS, has yet not taken any practical shape, despite being mentioned in the strategy documents of many Centers. We recommend that while subject related training can be held at the CG Centers, management related training can be imparted by appropriate NARS institutes.

6.26 There has to be a critical assessment of the commodity vs. eco-regional program approach. Lately, a shift towards latter has been noticed, where often CG Centers seem to have neither the comparative advantage nor the resources to address varying eco-regional problems. Also it is seen that medium-term plans are altered too frequently, which is often counter productive. It is not clear as to why a centralized system for research guidance is followed in the CGIAR when a globally decentralized approach for research priority setting is considered to be the most effective mechanism.

6.27 The CGIAR System should have a long-run vision and should not resort to change within the next 10 years. They should have different modules, programs, activities, and style of working with NARS depending on their size, maturity, and strength.

6.28 It is an irony that old institutions that have played major roles in the quest for food security are currently facing acute financial crisis, whereas newly created institutions seem to be better funded by the System. Sustainability of these institutions must, therefore, be considered a major issue by the CGIAR, especially when the CGIAR mission has clearly highlighted the need to cut in half the number of people — currently 800 million — lacking food security in the world.

6.29 The concept of inter-institutional linkages among CG institutes has not been practiced to the extent needed, especially given that such collaboration can enhance effectiveness and value of programs based upon systems approved. A matrix mode of management laying greater emphasis on an inter-disciplinary approach and inter-institutional collaboration must also be ensured. The suggested global challenge programs may be a right step in this direction. provided they are implemented in both letter and spirit.

6.30 The split mandate of IARCs is not desirable. For example, CIMMYT has a fractured mandate for wheat (bread wheat), the durum wheat covered by ICARDA. Yet ICARDA's domain is from Morocco to Pakistan only, although there are many other countries (like India) that grow durum and barley but do not receive ICARDA benefits. Similarly, IRRI's mandate of rice is also covered by IATA and WARDA in West Africa. The division of responsibility of one crop (like IRRI, CIMMYT) and multiple crop responsibility (like ICRISAT having to serve India and Africa) pose severe logistic, coordination, and other problems. Further, the inter-Center multidisciplinary programs like that of Rice-Wheat Consortium in network mode splits mandate and resources and is gradually corroding the credibility of the System as the CGIAR's interests and resources are thinly spread over a large number of activities. For household nutrition security, research support on crops such as soybean, mung bean, vegetable crops, etc., also justify CG support and must be addressed on priority.

6.31 Issues concerning governance, representation of various regions both in the institute management and in its governing bodies, gender balance, ensuring more time for scientists for field and laboratory work than the current trend of more desk-oriented work, linkage with NARS, critical programs requiring core funding support to meet expectations of NARS, transparency in the selection procedures of scientists and the management staff, including the Director General, etc., also need a fresh look for required improvement in future. All these measures will build confidence and thrust of NARS and ensure ownership by NARS.

6.32 To achieve more effective partnership, it is necessary that CG Centers give due credit to the scientific contributions provided by the scientists of national systems: In other words, the current trend of one-way traffic has to be made two-way traffic. Sharing the credit for contributions between CG Centers and NARS is also an important issue that needs urgent attention. Development of guidelines and directions in this regard will help develop confidence among the scientists working in different institutions in the national agricultural research system.

6.33 There is an increasing tendency on the part of donors to guide the research agenda using geographic and political considerations, rather than considerations that would stand scientific scrutiny. Such trends are dangerous and must be viewed seriously by the CGIAR to ensure international stature and the creation of GPG by existing institutes under the System.

6.34 There is a limit to the adjustment that can be made by the CGIAR System to the falling funding situation, particularly in unrestricted funding. The world has won some battles against hunger and malnutrition here and there. But the war is still on and the role of public science within this war will be even greater in future. Therefore, the World Bank and developed countries should continue to strongly support world public science facilitated by IARCs, as otherwise proprietary science will get the upper hand, which would be disastrous for developing countries in particular and mankind in general. Developing countries should start contributing more and more to the CGIAR and become proactive in articulating their needs and getting them redressed through partnership with IARCs. The culture of ownership of IARCs by developing countries should begin soon.

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# Annex 2: Appendix Tables

## Annex Table 1: Adoption and Impact of Improved Crop Varieties in India

| ***Crop*** | ***Region*** | ***Variety*** | ***Year*** | ***Adoption Rate (% area)*** | ***Impact*** |
|---|---|---|---|---|---|
| Sorghum | All India | All improved | 1998 | 65 | JKSH 22, a private sector popular hybrid containing ICRISAT materials |
| Pearl Millet | Rajasthan (India) | All Improved | 1996 | 56.26 | 228% grain yield gain, 12% fodder yield gain, 47% cost reduction, 60% change in total labor use, 140% change in female labor use, net farm increase of Rs.1134 ha compared to local |
| | | BK 560 | 1996 | 17.61 | 62% grain yield gain, 34% reduction in fodder yield, 25% change in female labor use, net farm income of Rs.922 $ha^{-1}$ compared to local. Widely adopted for downy mildew resistance |
| | Haryana | All improved | 1996 | 85.96 | 182% grain yield gain, 68% fodder yield gain, 47% cost reduction, 44% change in female labor use, net farm income of Rs.2062 $ha^{-1}$ compared to local |
| | | HHB 67 | 1996 | 38.69 | 129% grain yield gain, 23% fodder yield gain, 5% cost reduction, 21% change in female labor use, net farm increase of Rs.1484 $ha^{-1}$ compared to local |
| | Gujarath | MH 179 | 1995 | 31.17 | 247% grain yield gain, 72% fodder yield gain, 4% cost reduction, 170% change in female labor use, net farm income of Rs.2818 $ha^{-1}$ compared to local. Widely adapted due to disease resistance, short duration, high grain, fodder yield |
| | | MH 169 | 1995 | 23.73 | 448% grain yield gain, 108% fodder yield gain, 65% of cost reduction, 218% change in female labor use, net farm income of Rs.7350 $ha^{-1}$ compared to local |
| | Tamil Nadu | Pioneer | 1994 | 29.23 | 144% grain yield gain, 24% cost reduction, net farm income of Rs.3048 $ha^{-1}$ compared to local |
| Pearl Millet | Mahara-shtra | All improved | 1994 | 94.3 | 95% grain yield gain, 7% fodder yield gain, 43% cost reduction, 16% change in female labor use compared to local |
| ICTP 8203 | 1994 | 33.49 | ICTP 8203 | 1994 | 50% grain yield gain, 36% cost reduction, net farm income of Rs.386 $ha^{-1}$ compared to local. Widely accepted for downy mildew resistance |
| MLBH104 | 1994 | 22.85 | MLBH104 | 1994 | 61% grain yield gain, 39% cost reduction, 3% change in female labor use, net farm income of Rs.38 $ha^{-1}$ compared to local |
| Chickpea | Andhra Pradesh | ICCV2 | 1995 | 17.0 | 108% grain yield gain, 29% cost reduction, 11% change in female labor use |
| Madhya Pradesh | 1995 | 13.0 | ICCV2 | 1995 | 123% grain yield gain, 33% cost reduction, 25% change in total labor use, 65% change in female labor use, 624% higher farm income, 103% price premium compared to local |
| | Gujarath | ICCV1 | 1995 | 25.0 | 67% grain yield gain, 32% cost reduction, 10% change in total labor, 35% reduction in female labor use, 143% higher farm income compared to local |
| Pigeon pea | Kamataka | ICP8863 | 1993 | 59.0 | 43% yield gain and 42% unit cost reduction compared to local IRR 65%, NPV of US $ 62 m |
| Mahara-shtra (western) | ICPL87 | 1995 | 57.0 | 1995 | Short duration allows double cropping, rotation with pigeon pea helps maintain soil fertility, widely adopted |

*Source: ICRISAT, 2001.*

## Annex Table 2: Adoption and Impact of Natural Resource Management Technologies in India

| *Region* | *Technology* | *Year* | *Adoption Rate (% area)* | *Impact* |
|---|---|---|---|---|
| Mahara-shtra (India) | Raised bed and furrow | 1994 | 31.0 | IRR of 25.3%, Gender impact: higher labor productivity, easy weeding and harvesting, sustainability, moisture conservation, improved drainage |
| Mahara-shtra (India) | Dry seeding summer cultivation | 1996-97 | 75.0 | Dry seeding: sorghum<br>Yield increase 38.4%, income increase 98.5%, employment increase 13.6%, cost saving 17.1% |

*Source: ICRISAT, 2001.*

## Annex Table 3: Internal Rates of Return (IRR) of ICRISAT Technologies in India

| *Technology* | *IRR (%)* |
|---|---|
| Chickpea | 18.21 |
| Groundnut | 25.0 |
| Groundnut production technology | 25.0 |
| Pigeonneau | 65.0 |

*Source: ICRISAT, 2001.*

**Annex Table 4: IRRI-Bred and Other INGER-Provided Lines From NARS Released as Varieties in India**

| Designation | Origin | Name Given | Year Released |
|---|---|---|---|
| BG367-4 | Sri Lanka | ADT37 | 1987 |
| BG90-2 | Sri Lanka | Phant Dhan 4 | 1983 |
| BR51-46-cl | Bangladesh | - | 1979 |
| BR51-91-6 | Bangladesh | Radha | 1983 |
| B2983b-SR-85-3-2-4 | Indonesia | Mukhi (CTH1) | 1990 |
| Gama 318 | Indonesia | Avinash | 1985 |
| Intan | Philippines | Intan | 1975 |
| IR10781-75-3-2 | IRRI | KHP-2 | 1990 |
| IR13427-45-2 | IRRI | PY3 (Barathithasan) | 1983 |
| IR13525-43-2-3-1-3-2 | IRRI | IR62 | 1988 |
| IR17492-18-10-2-2-2 | IRRI | CO45 | 1989 |
| IR1561-216-6 | IRRI | Prasad | 1978 |
| IR1721-14 | IRRI | Paiyur-1 | 1979 |
| IR18348-36-3-3 | IRRI | IR64 | 1992 |
| IR1846-284-1 | IRRI | VL Dhan 16 | 1984 |
| IR19661-150-2-2-2-1 | IRRI | HKR120 | |
| IR19728-9-3-2 | IRRI | Pant Dhan 6 | 1986 |
| IR2061-213-2-17 | IRRI | IR34 | 1979 |
| IR2061-214-3-8-2 | IRRI | IR28 | |
| IR2071-586-5-6-3 | IRRI | IR42 | 1983 |
| IR2071-586-5-6-3-4 | IRRI | AU2 | 1983 |
| IR2071-625-1-252 | IRRI | IR36 | 1979 |
| IR2153-159-1-4 | IRRI | IR30 | 1979 |
| IR21820-154-3-2-2-3 | IRRI | ADT 38 | 1987 |
| IR28224-66-2 | IRRI | PR109 | |
| IR32307-107-3-2-2 | IRRI | IR66 | |
| IR3941-45-Pip2B | IRRI | Himalaya 741 | 1986 |
| IR442-2-24 | IRRI | Pani Dhan 1 | 1973 |
| IR442-2-58 | IRRI | Pani Dhan 2 | 1973 |
| IR5-114-3 | IRRI | Pankaj | 1969 |
| IR50 | IRRI | IR50 | |
| IR532-E-576 | IRRI | IR20 | 1970 |
| IR579-48-1 | IRRI | Palman 579 | 1979 |
| IR579-97-2-2-1 | IRRI | Rajendra Dhan 201 | 1979 |
| IR579-160-2 | IRRI | IR2 | 1970 |
| IR661-1-140-3 | IRRI | PR103 | 1978 |
| IR661-1-140-3-2 | IRRI | IR24 | 1972 |
| IR665-79-2-4 | IRRI | PR106 | 1978 |
| IR8-288-3 | IRRI | IR 8 | 1966 |
| IR9202-25-1-3 | IRRI | CTH3 | 1992 |
| IR930-67-2-2 | IRRI | Sita | 1972 |
| IR9224-117-2-3-3-2 | IRRI | IR50 | 1982 |
| IR9763-11-2-2-3 | IRRI | Pant Dhan 10 | 1992 |

# Annex 3: List of Working and Background Papers, Authors, and Peer Reviewers

## Working Papers

Barrett, Christopher B. 2002. *Natural Resources Management Research in the CGIAR: A Meta-Evaluation.*

> Peer Reviewers: Jock Anderson, Derek Byerlee, Dana Dalrymple, Hans Gregersen, Ted Henzell, John Lynam, Vernon Ruttan, Meredith Soule, Joachim von Braun, Usha Barwale Zehr

Eicher, Carl K. and Mandivamba Rukuni 2002. *The CGIAR in Africa: Past, Present, and Future*.

> Peer Reviewers: Malcolm Blackie, Dana Dalrymple, Bob Herdt, Alain de Janvry, Romano Kiome, John Lynam, Eric Tollens, Geoffrey Mrema, Wilfred Mwangi, Cyrus Ndiritu, Emmy Simmons, Moctar Touré

Gardner, Bruce 2002. *Global Public Goods from the CGIAR: Impact Assessment.*

> Peer Reviewers: Jock Anderson, Dana Dalrymple, Osvaldo Feinstein, Paul William Glewwe, Hans Gregersen, George Norton, Scott Rozelle, Vernon Ruttan, Sara Scherr, Sudhir Wanmali

Lesser, William 2002. *Reviews of Biotechnology, Genetic Resource and Intellectual Property Rights Programs.*

> Peer Reviewers: Ronnie Coffman, John Dodds, Robert Evenson, Brian Ford Lloyd, Anatole Krattiger, Steve Kresovich

Spielman, David 2002. *International Agricultural Research and the Role of the Private Sector.*

Macedo, Jamil, Marcio C. M. Porto, Elisio Contini, and Antonio F. D. Avila 2002. *Brazil Country Paper for the CGIAR Meta-Evaluation.*

Katyal, J.C. and Mruthyunjaya 2002. *CGIAR Effectiveness — A NARS Perspective from India.*

## Background Papers (Available upon request)

Ndiritu, Cyrus 2002. *CGIAR-NARS Partnership: The Case of Kenya.*

Romano, Luis 2002. *Colombia Country Paper for the CGIAR Meta-Evaluation.*