Agricultural Research and Extension- Priority Setting and Institutional Development[1]

C.Ramasamy and K.N.Selvaraj[2]

1. Background

Agricultural growth is vital for providing income and employment to large section of population depending on agriculture for their livelihood. Modernization of and growth in agriculture are needed to be kept apace with rest of the economy to sustain income and employment to this large section of the population. Research studies have unequivocally shown that investment on agricultural R&D is one of the prime factors to induce growth in agriculture. The R&D investment in Indian agriculture has contributed significantly for agricultural development. The role of Research and Extension in generation and transfer of appropriate technologies for farming needs to be constantly improved to achieve further increases in production. Agricultural research and extension systems in developing countries face new demands and challenges, arising from the process of economic liberalization and globalisation. To meet these challenges, research systems ought to have to undergo institutional, management and funding reforms and most strengthen linkages with clients and improve accountability and efficiency.

For India, livelihood security of the rural poor is at the centre stage of the development process with agriculture and rural development woven into it. Important priorities in agriculture in this regard include enhancing efficiency, promoting stability based technology and production systems, sustainability, addressing inter-regional disparities and promoting value addition. Food and nutrition security which includes food availability, accessibility and absorbability is a critical plank of overall development - both urban and rural.

This paper has attempted to understand the current status of National Agricultural Research, Education and Extension System (NARES) in India and indicate strategies and action plan to improve its functioning to match the requirements of agricultural development with specific focus on food security, poverty reduction, sustainable use of natural resources and agricultural production in the context of globalisation of Indian economy. Priority setting and institutional development in agricultural research and extension activities assumes greater importance given the new demands of changing social needs and the economy. Specific issues to be understood include:

- NARES and its transformation - mandate and its achievements, and how to make research system right-sized, responsive and efficient?
- What is the research output on investment made so far? Measuring research outcome in terms of increase in agricultural income, food and nutritional security, employment, sustained use of resources and poverty reduction.
- Research, education and extension intensities across the country and how they reflect the investment intensity in research, education and extension.
- Given the evidence of high returns to investment on agricultural research (and extension), why underinvestment in this sector?
- Role of human resources for enhancing agricultural research productivity and effective extension; and organizational, functional and policy changes needed to make agricultural education system more efficient and relevant for the present and future.
- Shifts which have occurred in the role of public and private sector in agricultural research and extension; forces driving the public and private sector; how both public and private performed in terms of cost effectiveness, innovativeness and quick responsiveness in meeting agricultural development needs and implications for research priorities and organization of research.
- Assessing areas of interface between public and private sector in agricultural research and extension and policy reforms needed to synergise the efforts.
- Prioritization in allocation of research resources with a major question of assigning weights across growth, equity, sustainability, food-nutrition security and trade objectives; and also allocation across agro-climatic zones and crops and other farm enterprises given the distribution of weights indicated above.

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[1] Prepared by C.Ramasamy and K.N.Selvaraj, Tamil Nadu Agricultural University, Coimbatore - 641 003.

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- Institutional mechanisms in research resource allocation and priority setting; constraints and needed modifications and normative standards in the existing systems.

The paper addresses the issues outlined above and attempts to throw more light on the issues and proposes an action plan for making National Agricultural Research, Education and Extension system to be more efficient, productive and responsive.

2. Institutional Morphology of Indian NARES

NARES has grown tremendously due to rapid change in research and development needs over the past half a century. Indian Council of Agricultural Research (ICAR) is the apex body guiding and directing agricultural research and education in the country. ICAR framework comprises its own institutes which conduct substantial part of agricultural research done in the Country, State Agricultural Universities (SAUs) - State level apex institution for undertaking agricultural research and extension and linkages with private sector and also overseas agricultural research linkages particularly with Consultative Group on International Agricultural Research (CGIAR). Indian private agricultural research is in- house research of private companies and private non-profit foundations.

The institutional morphology of Indian NARES got significantly transformed over the past five decades[1]. The Imperial (now Indian) Council of Agricultural Research (ICAR) was established in 1929. Birth of ICAR resulted in empowerment of agricultural research in India. Concomitantly, a number of central commodity committees were constituted to promote production of commercial crops. Funding of these committees from cesses was the first attempt to link research funding with the beneficiaries. In 1957, the first All India Coordinated project was started with the technical support from the Rockefeller Foundation. The project was multi-disciplinary and beginning of research planning on the basis of agro-climatic zones. ICAR was reorganized in 1965 for coordinating, directing and promoting agricultural research in the country. This led to centralization of funding, execution and management of research with greater autonomy and empowerment to ICAR. A Department of Agricultural Research and Education (DARE) was created in 1973 in the Central Ministry of Agriculture to establish direct linkages of the ICAR with Central and State Governments and international organizations. Major expansion under ICAR took place on the lines of commodity research.

In order to improve the agricultural education, SAUs were set up on land grant pattern of the American Universities. These newly formed universities with autonomous status received funding from the State governments to impart education on all aspects of agriculture on the same residential campus and integrate teaching with research and extension. In late 1970s, SAUs streamlined their functioning and all matters related to agricultural research in the States were transferred to the universities. SAUs saw a shot in the arm in 1979 by receiving the assistance from the World Bank to strengthen Regional Agricultural Research Stations under National Agricultural Research Project (NARP) beginning 1988-89. Another major project was launched to strengthen demand driven agricultural research in the country under National Agricultural Technology Project supported by the World Bank during mid 1990s.

Meanwhile CSIR, DBT, DRDO and DST supported agricultural research and extension directly or indirectly. With the advent of green revolution in late 1960s, industries both from public and private sector entered into agricultural research domain but in a limited way. Emergence of hybrids paved the way for the entry of private sector in seed research and this was followed by participation of transnational seed companies in seed research with the passage of new policy in 1988.

Alongside, the major activities of NARES got expanded in terms of basic and strategic research, applied and adaptive research, commodity and resource specific research, discipline based research, All-India Coordinated Research (projects), resource specific research, mission-mode research, conservation and exchange of germplasm, education and man power training; and research collaboration with CGIAR system and research foundations overseas - operationalised through DARE.

The National Agricultural Extension System (NAES) originated with the establishment of the Department of Agriculture in the Imperial Provincial Governments. In order to achieve a sustained rural and agricultural development, Community Development Project was launched in 1952. The launching of National Extension Service Programme in 1953 was another major step. With growth in agricultural research, front line extension work was initiated in ICAR and SAUs. A Department or Directorate of Extension has been in operation in the ICAR institutes and SAUs and the basic objective of these units are to conduct extension research, demonstrate latest technologies, offer feedback to scientists and provide training support to State Department of Agriculture. Another significant institutional development in the course of time has been the establishment of Krishi Vigyan Kendras (KVKs) with the objective to undertake front-line extension.

Subsequently, with the aim to achieve self-sufficiency in food production, Intensive

Agricultural District Programme (IADP 1961) and Intensive Agricultural Areas Programme (IADP) were implemented. The focus was on transfer of package of practices and supply of critical inputs to farmers. This was followed by Training and Visit System (T&V) commencing in 1974-75 with emphasis on single-purpose professional extension worker who will transfer the technology by personal contact with farmers. This concept was further strengthened through establishing research-extension-farmer linkages under the National Agricultural Extension Project in 1979.

Along with expansion of public extension system, both public and private industries got involved in dissemination of chemical and mechanical technologies since 1960s, followed by the entry of private sector in seed production and marketing. Both public and private systems used mass media in a big way. Latest to enter the extension system of the country is the NGO sector. The Directorate of Extension, Ministry of Agriculture, GOI plans extension activities at national level and disseminates information through mass media and publication of literature. National Institute of Extension Management (MANAGE) was established to train senior and middle level staff. Further, Integrated Rural Development Programme, Watershed Development Programme, Operation Flood, technology mission for crops etc. sponsored by government departments contain transfer of technology component. In 1994, the scope of extension was widened under the 'broad based agricultural extension' in farming system approach to include all land based activities. Now there is a well established extension network in the country.

India has the largest extension system in the world with about 1.5 lakh paid agricultural extension personnel catering to the needs of over 90 million farm families (Manage, 1999). One of the very recent initiatives taken by the government has been to launch the scheme of Agri-clinics. The plan is to set-up 5000 agri-clinics by involving unemployed agricultural graduates. The programme is financed through banks, and the government would provide 25 per cent of the cost as subsidy. The agri-clinics would be providing testing facilities, diagnostic and control services, and all kinds of agro-consultancy services, on payment basis. The institutional growth of ICAR-SAU system is shown in Annexture-1.

2.1. NARES Mandate and objectives

- To plan, undertake, aid, promote and coordinate education, research and its application in agriculture, agroforestry, animal husbandry, fisheries, home science and allied sciences.
- To act as a clearing house of research and general information relating to agriculture, animal husbandry, home science and allied sciences and fisheries through its publications and information system, and by instituting and promoting transfer-of-technology programmes.
- To provide, undertake and promote consultancy services in the field of education, research, training and dissemination of information in agriculture, agroforestry, animal husbandry, fisheries, home science and allied sciences.
- To look into the problems relating to broader areas of rural development concerning agriculture, including post-harvest technology, by developing cooperative programmes with other organizations such as the Indian Council of Social Sciences Research, Council of Scientific and Industrial Research, Bhabha Atomic Research Centre and the Universities.

2.2. Achievements

2.2.1. Impact on AgGDP

Indian NARES has made significant contributions in multiple ways to agricultural and non-agricultural sector which is reflected in improvement in productivity and high benefit-cost ratio of almost all cultivated crops; increase in social welfare in terms of food security poverty reduction; and better understanding of urgent need for conservation of natural resources. It has been shown empirically that the investment in agricultural research and extension is the main source of growth as exhibited by robust Total Factor Productivity (TFP) and comfortable rates of return to agricultural research investment in Indian agriculture (Evenson and McKinsey, 1991; Kumar and Rosegrant, 1994). Various studies conducted during the different time periods show that marginal internal rate of return to agricultural research and investment is highly rewarding (Annexure-1A). Estimated elasticity of agricultural research expenditure by public sector on agricultural GDP is highly significant showing that 10 per cent increase in public sector expenditure on agricultural research and development would induce agricultural growth by 2.4 per cent at constant prices (Annexure-2). Similarly, crop wise analysis also indicates that R&D induced supply shift in major crops (Annexre-3).

2.2.2. Growth in TFP

Total Factor Productivity (TFP) is a true measure of economic efficiency[2]. The TFP index of crop-livestock reached to 290 per cent in 1991-92 from the base year (1964-65 = 100). Research contributed to 48 per cent of this TFP growth (Chand, 2000). The national-level evidences showed that output growth of livestock sector touched nearly 4 per cent per annum during 1980s and TFP growth jumped to nearly 1.8 per cent, contributing about 45 per cent to total output growth. TFP growth has contributed roughly 1.1–1.3 per cent per year to the growth of crop production in India. Public agricultural research accounted for nearly 40 per cent of TFP growth between 1956 and 1987. Marginal impact of research on TFP was 50 per cent higher than before the Green Revolution and 17 per cent higher than in its early years. Comparison of marginal internal rates of return to public and private research investments showed that the returns to public agricultural research were greater than 50 per cent (Chand, 2000).

2.2.3. Adoption of Modern Crop Varieties

National Agricultural Research System's (NARS) contribution to the number and composition of varieties released are well known for all crop categories. It is more dominant for rice and wheat. About 2300 improved varieties of crops were developed and widely adopted by the farmers. Area under Modern Varieties (MVs) of major grain crops is growing steadily. During 1970s about 30 per cent of the area was planted with rice covered by MVs and it increased to 70 per cent during 1990s. About 90 per cent of the area planted with wheat, and 50 per cent of the area planted with coarse grains were covered by MVs varieties during 1990s (Annexure-4). Modern varieties of rice have spread to almost all areas with assured irrigation (Annexure-4A). Apart from high yielding varieties of rice, hybrid rice is found to break the yield barrier. The rigorous research efforts on hybrid rice over the last decade led to the release of 19 rice hybrids by the public sector, and seven-eight hybrids are marketed by the private seed sector. Average yield gain of hybrid over the popular inbred varieties was 16 per cent. Similarly, in case of wheat, the technical change contributed 34-51 per cent in increase in wheat productivity (Pal and Joshi, 1999).

In case of sorghum and pearl millet, adoption of improved varieties resulted in significant yield gains, reduction in unit production cost, and yield stability. About 182 improved cultivars with multiple traits were developed during 1962-98 period (Pal and Joshi, 1999). Much of the growth in maize production was due to the adoption of new seed-fertilizer based technology. In the case of pulses, the production increase was led by yield enhancement. Oilseeds production has also shown substantial increase after the government-sponsored programme on Oilseeds Mission launched in 1987. In the case of sugarcane some studies revealed that 50 to 70 per cent increases in productivity attributed by High Yielding Varieties (HYVs). The increase in sugarcane acreage and number of sugar factories clearly indicated contribution of varieties and inputs. The improved Co varieties not only yielded considerable benefits but also revolutionized the sugar industry in India. A large number of high yielding improved varieties of fruits, vegetable crops including potato, tuber and plantation crops have been evolved together with appropriate production and protection technology suitable for varying agro-climatic regions and situations in the country. The release of improved cultivars at national level has lead to substantial improvement in the overall productivity of the country. For instance, more than 35 HYVs and improved technologies for potato production have been developed so far.

2.2.4. Poverty Reduction

The effect of agricultural research and extension on improving the purchasing power of the poor-both by raising their incomes and by lowering the prices of staple food products-is probably the major gain realized in developing countries. Hayami and Herdt (1977), Pinstrup- Andersen *et al.,* (1976) and Hazell and Ramasamy (1991) provide strong evidences that the primary nutritional impact for the poor came through the increased food supplies generated through technological change. Further, the profitability of modern farming systems has also been maintained despite falling food prices (in real terms), owing to a steady decline in the cost of production.

Empirical studies proved that there is a strong and positive association between research outputs and poverty alleviation. As a result of various programmes, including investment in agricultural research and extension, the rural poverty ratio declined from 45.65 per cent in 1983-84 to 27.09 per cent in 1999-00 (Annexure-5 and 5A). Fan *et.al* (1999) found that among the various indicators, agricultural R& D is found to have higher marginal impact on poverty reduction and TFP realized is next to roads (Annexure-6). Agriculture still needs to play a key role in supplying adequate food at affordable prices to ensure that poverty remain low. Since both agricultural production and productivity growth were largely stagnant during 1990s, the so called "trickle down" benefits of agricultural growth on the rural poor were much smaller (Annexure-7). Since 1990s, the agricultural investment in India has stagnated. Without investments in agriculture, the poverty would be much higher today. One result of stagnation in investment was that poverty declined at a lower rate in 1990s than in the 1970s and 1980s.

2.2.5. Growth in Trade

Adoption of improved varieties resulted in significant yield gains, reduction in unit cost of production and surplus supply in many crops. Despite growing domestic demand, India exports a variety of commodities and gains sizable foreign exchange. Domestic Resource Cost (DRC) estimates indicate that it is cheaper to produce locally and export the most of commodities to world market (Ramasamy, 2003). Exports of agricultural commodities in the post reform period increased consistently and grew at the rate 11.58 in rupee terms respectively at current prices in the period between 1970–71 and 1990–91. For 1990s export of agricultural commodities recorded 16.83 per cent at current prices. The import content of agricultural sector is insignificant as compared to that of non–agricultural sector and as a result, agriculture was found to be the net foreign exchange earner for the country.

Agricultural imports grew by about 11.03 per cent in rupee terms in the pre reform period, which is almost equal to the export growth. However, during the post reform period, agricultural imports grew more exponentially at the rate of 15.99 per cent in rupee terms, however growth is not faster than exports. The major import component is food and related items in which pulses and edible oils form major share. The increase was essentially on account of the sharp increase in imports of edible oils. The ratio of balance of trade to GDP in agriculture has also improved in the post-liberalisation period due to higher export growth. The ratio of agricultural trade (exports and imports) to agricultural GDP was less than 10 per cent in 70s and 80s, but the ratio reached maximum of 12.06 per cent in 1995–96. The outcome of agricultural research and extension is one of the important factors for faster growth in agricultural trade during 1990s.

2.3. Failures

Intensive use of irrigation, fertilizer other agricultural inputs for crop production in Green Revolution areas are seen as the major causes of problem of soil salinization, groundwater pollution, nutrient imbalances, emergences of new pests and diseases and environmental degradation. Rising biotic pressure and lack of suitable land management system and inputs to realize optimum natural resource potential in fragile and marginal environments, including rainfed areas threaten agricultural sustainability. These problems led to land degradation, loss of biodiversity, soil erosion, water logging, water pollution, deforestation and environmental pollution resulting in diminishing farm efficiency and falling crop productivity. The present level of research and extension intensity is inadequate to address these challenges. Therefore there is a need for paradigm shift for designing new production system aligning fully with carrying capacity of the natural resources.

Policies, so far, have been focused more towards irrigated agriculture to specifically increase food grain production. But it is argued that the productivity returns to public investment leading to economic growth have substantial trickle down benefits for poor not only in irrigated areas but also those residing in less-favoured areas (Fan and Hazell, 2000). Less-favoured areas in India characterized by resource-poor, small and marginal farmers, poor infrastructure and supporting services cover 70 percent of cropped area, contributing nearly 40 percent of the total agricultural production and account for most of the commodities which are in short supply (Kanwar, 1991; Rao, 1991). But research investments addressing the problems of dryland agriculture is proportionately smaller leading to lesser priority for this segment. As a result there is a lower performance of the research system in replacing existing technologies by new ones in rainfed than in irrigated areas. This may be partly because of the failure on the part of the researchers in targeting farmers' need precisely and also due to the lower research intensity in the rainfed areas. While rice and wheat received enormous research support, coarse cereals, horticultural crops and natural resource management received lesser attention. Similarly, livestock, fisheries, forestry sector which have shown significant growth in the recent past, are yet to be developed fully.

Limited breakthroughs in the development of input responsive and drought tolerant crop varieties for dryland agriculture are partly responsible for low productivity growth. The contribution of both the public and private extension agents (farmers' organizations, producers' co-operatives, input firms, media and voluntary organizations etc.) vary widely and their presence is more skewed towards well endowed regions. Even in those regions where there is some significant presence, there has not been any integration of efforts due to various agencies. A review of evaluation studies on the T and V system revealed its impressive gains (in terms of productivity gains) in irrigated areas and its failure in making impact in the larger part of rainfed areas.

With GATT agreement and WTO in operation Indian agriculture with all its structural weakness must compete with highly commercial agricultural systems of the developed countries. In this context there must be sufficient expertise in the agricultural universities and ICAR institutes to develop cost effective technologies ensuring the quality traits of the commodities for exportability. So far Indian agricultural research system concentrated only on developing and disseminating productivity enhancing technologies. In this direction there is a need for a shift of research from production system to consummation and this forms a prerequisite for promoting exportability. Indian NARS has not cared adequately on basic research, which is critical for understanding of basic phenomena, required for making breakthrough in understanding of science. These breakthroughs will be a critical input for applied research to overcome yield stagnation and building desired crop characteristics.

2.4. Performance Evaluation Vs Budgetary Support

Total government expenditure, expenditure on agriculture and allied activities and its percentage share in total expenditure are summarized in Annexure-8. Share of government expenditure on agriculture to total expenditure has not increased over years but declined marginally and at present agriculture shares only 5.2 per cent of the total public outlay. Falling real public investment in agriculture is a cause for major concern. Public expenditure on agricultural research and development (at current prices) went up from Rs 257 crores during 1970s to Rs 2925 crores during 1990s. Similarly, public expenditure on agricultural research and development (at 1980-81 prices) went up from Rs 434 crores during 1970s to Rs 1086 crores during 1990s (Annexure 9). Public expenditure on R&D (at current prices) grew at the rate of 19.21 per cent during 1970s thereafter it declined to 14.61 per cent during 1980s and 8.48 per cent during 1990s. In real terms also, same trend was observed. The share of agricultural research and development in the AgGDP is less than one per cent in all the decades.

Given the budgetary provisions for NARS, is there adequate pay-off? Do investment in agricultural research worth to the society? How to evaluate the impact on investment made? What are the performance indicators? The performance of agricultural research and extension investment can be examined by a number of indicators. The contribution of NARS to growth in Agricultural Gross Domestic Product (AgGDP) could be the most important macro-level indicator. Growth in AgGDP will impact a number of other things such as per capita income, poverty reduction, food security and household livelihood, etc. Spread of levels of improved crop varieties, production technologies and management practices, improvement in agricultural productivity due to single resource / all resources put together as Total Factor Productivity (TFP), reduction in cost of production, spread of sustainable technologies, quality of products (in terms of market demand and consumer preference), contribution to agricultural exports and import substitution, improvement in human resource engaged in agriculture, etc., are indicators which could be considered for performance evaluation. Performance of agricultural research in ensuring promoting equity to and among the agriculturally dependent population, efficiency (in the form of efficient use of resource / input) and sustainability (of natural resources) can form reasonable indictors. As a single measure, rate of return to investment in national agricultural research could be a good indicator. The marginal return to agricultural research and extension in India are reported to be robust and is reported elsewhere in this paper. Hence, the returns far outweigh the budgetary support in India. To make research more effective in national context and to ensure equity across commodities, regions, stakeholders, etc., there appears to be a strong case for raising the budgetary support to agricultural research, education and extension.

2.5. Size of NARS

In terms of number of institutes, centers, directorates and projects, the growth of NARS has been significant. The underlying idea has been to encourage region / zone / ecosystem, commodity and issue / theme focused research. Though desirable, multiplication of units has resulted in overlapping of research work, lesser productivity per unit of research resource, more competition for available financial resources ending up with inadequate operating capital per research unit and scientist, under-investment in research infrastructure, declining marginal productivity of scientist and poor coordination among units. Dual control of SAUs, by ICAR and State Governments often leads to conflicting interests and misallocation of resources. Growing number of SAUs is a result of political decision often defeating the original concept of SAUs combining crop production, animal husbandry, horticulture, forestry, home science, agricultural engineering and fisheries, but get bifurcated / trifurcated into veterinary university, horticultural university, etc.

Although Indian NARS have grown in size and efforts, they are still dominated by government funded and administered institutions. There have been some initiatives like provision of contract research, rationalistion of seed regulation and entry of trans-nationals in recent past to diversity the NARS by encouraging private sector and NGOs. These efforts should be strengthened in future for efficient provision of research and extension services to farmers through diversified institutional arrangements. It is very important that Indian NARS not to grow in quantitative terms but in quality and productivity dimensions in the future.

3. Research Impact

3.1. Research Output

With one of the largest agricultural education, research and extension system in the world, research output over the past almost half a century has been very impressive. NARES, for example, released 2300 varieties (*www.icar.org.in*) and hybrids covering almost all crops. Crop production technologies and crop management practices have been evolved to meet the location specific needs of the farmers in the entire country. There are alternative 'economics tools' available to measure the research output. One can assess, due to research how much (i) the crop yield frontier been shifted and / or (ii) the input use efficiency has increased and / or (iii) sustainable use of resource use and cultivation practices have been achieved. To measure the impact of research output, a log-linear equation was estimated relating yield as dependent variable and research expenditure, value of inputs and irrigation as explanatory variables[3]. In other words, the equation examines the effect of R&D on cost reduction in production of major crops viz., rice, wheat, groundnut, sugarcane and cotton.

Results show that agricultural research expenditure has positive and significant influence on yield and the coefficients are ranging from 0.01 - 0.77 (Annexure 10). Two scenarios were simulated to estimate the effect of increased research expenditure on the cost reduction. It is assumed that research expenditure increases at an annual rate of 5 and 10 per cent respectively in Scenario I and Scenario II for the following years (2002-03 to 2005-06) with cost of cultivation and area under irrigation remain constant at the current level (2001-02).

A 5 per cent annual growth of research expenditure induces output supply to shift outwardly resulting in cost reduction by 1.6, 0.94, 0.9 and 3.77 per cent respectively for rice, wheat, sugarcane and cotton in the year 2005-06 compared to that of base year (2001-02). Similarly a 10 per cent annual growth of research expenditure results in cost reduction due to output increase and estimated cost reduction would be 3.18, 1.91, 0.17, 1.80 and 7.63 per cent for rice, wheat, groundnut, sugarcane and cotton respectively by the year 2005-06 compared to that of 2001-02 (Annexure-11). The results clearly reveal that investment on agricultural research and development (research output) have enabled the farmers to reduce the average cost of unit output due to technological improvement ensuring income and food security in India.

3.2. Research outcome

Research outcome may be reflected in terms of (i) increasing farmers' income (ii) food and nutritional security (iii) sustainable use of resources and (iv) poverty reduction.

A composite index was constructed to measure the research outcome. Per capita agricultural GDP for income entitlement, per capita food grains consumption for food security, per capita egg, milk, fruits and vegetables consumption for nutritional security, agricultural labour force for employment guarantee, poverty ratio for equity, and land productivity, extent of irrigation and fertilizer consumption for efficiency, use of bio input (biofertilizer and biopesticide) for sustainability were considered to construct the index to measure the research outcome[4].

Using the composite index the impact of agricultural research and development expenditure on overall welfare of the economy was estimated with a long-linear equation[5]. The results suggest that agricultural research and development expenditure has positive impact on overall growth of the economy and estimated elasticity is 1.98 implying that 10 per cent increase in agricultural R&D improves overall welfare by 19 per cent emphasizing the need for sustaining and increasing the spending on agricultural research and development (Annexure-12). The index constructed is shown in Annexure-12 A.

4. Research, Education and Extension Intensities

The Research, Education and Extension Intensities can be measured in terms of number of institutions, scientists and private and public expenditure in NARES. At present, there are 34 SAUs, 4 Deemed Universities, 45 ICAR Institutes, 30 NRCs and 262 KVKs. This apart 516 research projects are undertaken through network processes. All the State Governments implement agricultural extension activities through the line departments. Within the State, extension personnel are located upto village level.

India has the one of the largest agricultural research and education system in the world employing about 33020 scientists (Annexure-13) and most of them are engaged in triple functions of education, research and extension. But the investment per scientist is Rs.4.21 lakhs in 2001-02 which has declined from Rs.4.32 lakhs in 1992-94 period. Research investment per ha of Gross Cropped Area (GCA) was as low as Rs.71 during 2001-02. Scientists intensity per 1000 ha of GCA was 8.34 during 1992-94 and declined to 5.90 in 2001-02.

Investment on public research has increased manifold and reached Rs.13890 million by 2001-02 from Rs.409 millions in 1970-72. Given the size of population depending on agriculture for their livelihood, the public expenditure is still low with only 0.32 per cent of Agricultural Gross Domestic Product (AgGDP). Thus the research intensity is much lower in India. Statewise analysis of intensity confirms the low research intensity in India (Annexure-14). However, some of the States perform better than others in terms of research intensity. Orissa and Himachal Pradesh invest 0.76 and 0.55 per cent of AgGDP on agricultural research and education. The performance of Uttar Pradesh, West Bengal, Bihar and Maharashtra are much poorer with 0.04 to 0.08 per cent of AgGDP. The Southern States also invest much less, thus showing low research intensity. Certainly, India must increase the share of AgGDP as investment in agricultural R&D, which will bring substantial benefits with a time lag of 3 to 10 years.

Apart from governments, industries in public and private sectors invest in research on seeds, fertilizers, machinery, etc. The contribution of public sector industries was estimated at 5 per cent and total public sector share in total investment is reported to be 85 per cent leaving 15 per cent to private sector. In the year 2001-02, the country spent 0.32 per cent of AgGDP on agricultural research. Efforts should be made to raise the intensity to at least a commonly described norm of one per cent of AgGDP as suggested by the World Bank (Pal and Singh, 1997). It is important to assess the factor shares, *viz*., salary, capital and operating expenses in research expenditure. While salary component keeps rising, the share of operating and capital costs has decreased over the years. By 1997, the share of 'operating expenses' was reported to be about 20 per cent (Suresh Pal and Singh, 1997). Estimate for Tamil Nadu Agricultural University for the year 2003-04 shows similar picture (20 per cent) with 10 per cent going for capital expenses. The share of operating expenses in total expenses in India appears to be lower than that even in other developing countries. Thus there is a strong case for raising the shares of operating and capital expenses. Which is of course achievable through improved financial planning and by motivating scientists to raise research funds.

Unless there is strong extension, the full potential of research output cannot be realized. Though GOI provides support through various agricultural extension programmes with cash and subsidies, actual implementation of extension activities rests with the States. ICAR incurred an expenditure of Rs.400 million on agricultural extension in 1997-98 and it rose Rs 900 million in 2001-02. The investment on agricultural extension, which was only Rs.59 millions in 1960-62 rose to Rs.3008 in 1992-94 (Suresh Pal and Singh, 1997). For the same period, investment on extension as per cent of AgGDP rose from 0.09 to 0.55. That is, investment per ha increased from Rs.2 to Rs.6.48. Extension investment per extension worker was Rs.11.40 lakhs per annum for the State of Tamil Nadu[6]. The share of States in national investment has marginally declined form 97.87 per cent in 1960-62 to 92.87 per cent in 1992-94. For the State of Tamil Nadu, it was 93.40 per cent for the year 2002-03. The performance indicators of extension organizations can be seen in Annexure 15.

Pal and Singh (1997) report that, of the total investment of agricultural extension of Rs.3955 millions, government extension (main) spends 76.1 per cent, ICAR/SAU 14.1 per cent of resources, public industries 2.1 per cent and private system 7.7 per cent for the year 1994-96. It is not likely that this pattern has changed by 2003-04 except that the contribution of NGOs may have increased marginally. Extension investment for the States vary widely with 0.10 per cent of AgGDP in Punjab to 0.42 in Tamil Nadu and 0.54 in Himachal Pradesh for the period 1992-94. Substantial part of technologies available in shelves of laboratories and universities have not reached the end users, often, due to absence of effective extension system which suffers from want of manpower and operational expenses. This certainly warrants to increase extension intensity in the country, as there is tremendous scope for yield increase given the current stock of technologies transferred to the farmers. New generation of agricultural technologies are more knowledge intensive, complex and broad based with business orientation. Dissemination of these technologies needs more intensive extension efforts supported by adequately trained (both in knowledge and skills) extension functionaries.

5. Public VS Private Research

5.1 Growth and Performance

Agricultural research in India is largely public - funded. Overall, in the country, ICAR Institutes conduct about 43 per cent of the research done in India; SAUs about 33 per cent; the private sector 16 per cent; and International Centers about 8 per cent. About 16 per cent of Indian agricultural research is in-house research of private companies and private non-profit foundations (Evenson *et al*., 1999). Although agriculture is a State subject in India, major component of the research system were initiated and funded by Central government. The SAUs are autonomous institutions for meeting educational and research needs of the States. The number of ICAR centers and SAUs have increased overtime whose mandate include research on all crops *viz*., cereals, pulses, oilseeds, sugarcane, cotton, fibre crops, horticultural crops, livestock, poultry, forestry, home science, etc. ICAR has its centers throughout India. Regional research needs are met by teaching campuses and regional research centers of SAUs. The public sector research has expanded much after independence in a consistent manner. It has not diminished its activities though there was good amount of private research.

Private research continued to be limited until Independence. Since then, Indian firms in most agricultural input industries have progressed from importing inputs to conducting research on them. Private sector has increased its investment rapidly over time (Annexure-16). Evidences show that private sector research and development was significant accounting for more than 11 per cent of TFP growth. Private sector undertakes research for the development of embodied technologies, *viz.* chemical, mechanical and biological. With the adoption of new seed-fertilizer technology in the mid-sixties, there was phenomenal growth in the industrial sector for the production of inputs. The entry of private sector in seed research started in the 1970 with the popularization of hybrids. The late 1980s marked real beginning of private sector in seed business. There have been some initiatives like provision of contract research, rationalization of seed regulations and entry of transnational, in the recent past to diversify the NARES by encouraging private sector and NGOs. Policy reforms of lifting restriction on entry of foreign owned companies in seed research and import of germplasm for research purpose, supported by economywide reforms have encouraged private research investment. With the introduction of Farmers' Seed Protection and Breeders Right Patent Act, it is expected that the pace of private research investment particularly in bio-technology can be further accelerated.

In contrast to coverage of all crops by public sector, private sector research comprising chemical companies, fertilizer companies, seed companies, etc., is focusing on development of new products, most of them are chemical fertilizers, pesticides, fungicides, herbicides, seeds-mostly hybrids seeds of sorghum, bajra, maize, cotton and vegetables. With the adoption of new seed-fertilizer technology in the mid-sixties due to public sector research, there was phenomenal growth in the industrial sector for the production of inputs. The entry of private sector in seed research started in the 1970 with the popularization of hybrids particularly in millets, and in cotton. Private research and development in seeds grew since late 1970s with seed companies mostly concentrated in Maharashtra and Andhra Pradesh.

Hindustan Lever Ltd. and Cargill entered the seed industry in the year 1987. American Hybrid and Mahyco are other seed companies whose presence was conspicuous. These companies were followed by most of the large Indian and Foreign companies such as ITC, Sandoz, Hoechst and Ciba-Geigy. Turnover of key Indian seed players and export of seeds as late as 2000 is shown in Annexure 16.

Public sector research made substantial contribution during 1970s through 2000 by evolving varieties in almost all crops. The rice growing States released a large number location specific, growing-period specific, soil specific, pest / disease tolerant and consumer preferred varieties. There was ceaseless flow of technologies covering soil and water management, nutrient management, plant protection and dryland crops. Private sector did not enter into crops and technologies, which did not bring higher profits. Mostly materials, which came out of private research, were costly and not favourable to small and marginal farmers. Research on agricultural machinery was conducted both by public and private sector. However machinery and equipments developed by private firms spread faster due to their market network. Tractors were imported during 1960s and later, many Indian companies entered manufacturing tractors either as a joint venture with multinationals or independently.

During 1990s International Agricultural Research Centre, ICRISAT, spawned a new policy of providing germplasm of their mandate crops to private sector so as to facilitate release of varieties and hybrids. Meanwhile ICRISAT also exchanged substantial amount of germplasm with NARS since its inception. At the same time public NARS did not support private sector research except undertaking verification and efficacy trials on cost basis.

By and large, public and private sector ran parallel without affecting each other. While public sector research was more of policy driven, private sector research was market-driven. Many products of agricultural research are public goods which the private sector lacks incentives to produce. Small farmers with limited purchasing power are not organized to finance research. Private firms, with limited opportunity to appropriate profits from provision of technologies, will not invest sufficiently in research. Because of these market failures and long-term risky pay-offs, the public sector must fund most agricultural research. Although private sector funding for agricultural research is expanding rapidly, due in part to the application of strong intellectual property protection, this private research often relies on knowledge provided by publicly funded research.

Many researchers view, in terms of cost effectiveness, private sector performs better. Focused product development, timeframe for delivery of the research product, productivity of scientists, most effective use of research infrastructure, and competitioness of rivals results in higher resource efficiency in private research. In all the above dimensions, public sector is lagging behind.

Viewed in terms of innovativeness, it is a mixed bag. However, in public sector, speed of technology development is slow, which in a way, provides a sound basis for innovations with minimum level of errors. Hence public sector innovations are more sustainable. It is clear from long standing of public sector varieties and hybrids. In emerging areas such as bio-technology and horticulture, select MNCs are observed to be more innovative as they are confining themselves to one or two crops or few select products. Public sector has much larger responsible role such as maintaining gene banks, basic research, research for marginal and backward areas, research on sustainable use of resources, etc. Hence, it may be difficult to draw a concrete conclusion on innovativeness of public and private sector.

As regards quickness of responses in meeting the agricultural development needs of farmers, there is a notable change in recent periods than earlier periods in the public sector research. Farmers awareness and lobbying and globalisation have resulted in achieving quick responses in recent years and it will continue to be so in the future as development will be market driven primarily.

5.2 Interface

Private sector research is expanding rapidly especially in hybrid seed and horticulture. There is also a significant private input to R & D on agro-chemicals, machinery, agro-processing, livestock feed and livestock health products. In general, private sector research is strong resource-wise and result-wise. Still, there is a weak linkage between private and public research. Certain level of mistrust exists between the two groups of researchers. Basic philosophy of public research aims at larger social benefits. Contrarily, private research investment is profit-oriented. Also there is no mechanism and agreed procedures for systematically tapping private sector funding to support problem-oriented research in public institutions. In recent years the linkage is becoming more conspicuous as ICAR has taken a policy to encourage public-private partnerships.

Some concerns are raised about the role of private sector. Private investment leads to proprietary technology and will it benefit poor farmers? Will private sector research address the problems of food security, protection of the environment and poverty reduction? The increasing rate of investment by private sector the world over in bio-technology and other emerging areas causes worry among developing country-farmers as the seed cost will be prohibitive and not affordable by them. The fact is that, while private sector is investing more on areas such as biotechnology and environmental issues, the sector makes use of research findings coming from the public sector. Currently, most of the GM crops are owned by MNCs and corporate companies. If this trend continues, the full spectrum from upstream research to production and distribution could eventually be under the control of a few global corporations. This is where there is a strong case for not weakening CGIAR system and public NARS. But many of the international donors and governments in both developed and developing countries are not rising up to occasion to counter this kind of development. Strong public research programmes are needed to address this trend.

Despite best efforts for strong interfacing between the two sectors, given the their different objective functions (and philosophy), there will be lesser incentives in developing countries to have a desired level of 'coming together' between private and public sector research. Hence we need to assemble the best scientific talent available to address the urgent problems affecting food security, environmental sustainability and even export promotion.

Positive and high returns to research investment in public sector is proved time and again and so no denying the fact that investment in public sector research must continue. Further, it may pay much dividends if NARS - Public (in the case ICAR/SAU) may seek the views of corporate leaders on ways in which the private sector could contribute to such research and technology transfer, while keeping in view the particular interests and accountabilities of the private sector and the potential of the vast public agricultural research infrastructure in the country. The institutionalization of the priority setting mechanism will clearly facilitate the functioning of public sector research institutions towards that end. In that case, ICAR/SAUs may develop mechanisms for institutionalizing mutually acceptable procedures in order to forge new alliances, which may address some of the key socio-economic issues such as food security and quality of environment.

Public sector, however, may play the regulatory role by monitoring the activities and products of private sector. Scope for collaborative opportunities between the two sectors in areas of environment, plant biotechnology, genetic conservation, seed production, information system and training are really tremendous. The writing on the wall is that more reforms in the existing organization of research is needed to make research more attractive to both private and public sector. Both the institutions must be given more freedom to collaborate, generate own revenues and also enforce stronger enforcement of contracts and strengthening of IPR.

5.3 Why underinvestment?

The share of agricultural research and development in the AgGDP is less than one per cent in all the decades. It is too low as compared to the developed countries with 2.5 per cent share. There is a clear case of underinvestment in agricultural R&D despite higher rates of marginal returns from the investment made. With the growing demand from various sectors of the economy for investible resources, policy makers and financial managers often allocate the resources according to pulls and pressures from the various sections of the society. Allocation is not guided by the returns to investment and is more informal. Governments, both Centre and States, offer huge subsidies to various sectors including agriculture, and often this leads to resource crunch resulting in to lesser allocation. Investment vs subsidy will continue to discourage agricultural investment. The principal factor which guides the financial managers is the demand for food security and poverty reduction in allocation decisions. Commercial potential of agricultural sector is often ignored since the R&D investment in agriculture will strongly influence commercial agricultural production, and few direct consequences of which are income and employment generation for the agricultural dependent population. Often, policy makers fail to precisely look into various implications of resource allocation. Present research investment on agricultural R&D is the divided responsibility between Central and State governments. Perceptions and priorities across States vary leading to different degrees of investment intensity. Agricultural research managers do fail frequently to impress upon the macro policy makers on the need for adequate investment in agricultural R&D. For example, the share of agricultural research has lost ground from 20 per cent of all research funded by Central government in 1960-80 to under 12 per cent by the late 1980s and major increases in allocations have gone to the Department of Science and Technology and to space research (Annexure 18).

Change in policy, which leads to break of consistency has also contributed for under investment. The phases of change in the investment correspond to organizational changes in the NARS. 1960s experienced low and declining Central investment due to shift from multi-channel research funding to centralized funding to the ICAR. Establishment of SAUs accelerated the State funding in 1960s and reorganization of ICAR in 1973 led to substantial increase in the Fifth Five Year Plan period. Implementation of National Agricultural Research Project (NARP) was a boon to strengthen regional research activities in the entire country. The rate of increase in State agricultural R&D funding stagnated or marginally declined in most of the States during 1990 through 2003 due to financial crunch experienced by various States. Thus changing emphasis on the structure of NARS over time has led to stagnation in investment. Governments must realize that we have to support more and more farmers, as a greater diversity of production conditions and constraints are to be addressed both in the present and future. As agricultural economy grows, the amount of resources that can be allocated to agricultural research, education and extension must grow.

Therefore, to attain sustainable growth in agriculture, provision of adequate public funds for research and development on a predictable basis is important. Hence, expenditure reducing policies should be guided by careful assessment of cost-effectiveness of on-going projects rather than by indiscriminately cutting across the board. Compared to other alternatives, the investment in agricultural research and extension is much more productive in terms of accelerating the pace of development. High rates of return underscores the need for higher allocations of public funds to research and extension. There is a considerable expansion in the research agenda in recent years requiring more research resources. In spite of increasing role of private sector in agro-biological research, a vibrant public research system should continue. Public research should concentrate on developing the cost-effective technologies with quality trait in order to enhance the competitiveness of agricultural products both in the domestic and international markets. This will largely help in poverty reduction in coming years. Further, various policies should be augmented for encouraging private investment.

6. Human Resources

Knowledge has always been the prime mover of prosperity. Agriculture, of late, is emerging as knowledge intensive due to emerging scenarios particularly in the globalised context. Currently growing resource scarcities of land and water, emergence of information technology, bio-technology, space technology, weather forecasting, disaster management, etc. exert a strong influence on agriculture. Developing human resources to face the new challenges does not require any emphasis. 'Land Grant System' in India largely, paved the way for sufficient skilled manpower to manage its agricultural research and education system. However, there is a continuous need for sufficient skilled and high quality man power to take agriculture in India into 21st century which will be characterized by more competitiveness.

6.1. Quantity

About 34 SAUs, 4 Deemed Universities, a number of conventional universities, private agricultural colleges and agricultural institutes admit about 17000 students annually[7]. The size of qualified candidates is burgeoning year after year. By and large, it can be safely concluded that adequate number of formally qualified candidates are churned out to meet the needs of agricultural and related sectors. The number of unemployed agricultural graduates provides strong evidence that qualified manpower is not utilized properly.

The agricultural education system in the country offers degree programmes in 11 specific discipliners in agriculture and allied areas, industry, banking and cooperation. About 5000 candidates are admitted for postgraduate studies. Postgraduates are specialized in 55 different fields. It is, by and large, an optimum blend of different disciples as they are demand driven. To meet the demand for low level educational needs, a number of Institutes are offering diploma courses and certificate courses.

6.2. Quality

To propel Indian agriculture into the 21st century, the quality, technical skills and management of agricultural manpower must improve in consonance with rapidly changing global market requirements. As more number of players entering agricultural educational fields offering services, monitoring of quality of education becomes difficult. Obviously, there is a decline in the quality of agricultural education, specifically in private and public supported colleges affiliated to conventional universities. Many of SAUs also do not rise upto the set standards in education. Plethora of institutions offering certificate and diploma courses do not have the desired level of accountability in offering quality education.

As regards ICAR-SAU system, imbalanced staffing, academic inbreeding and falling quality of education add to the problem of underperformance of the system, linked with inadequate funding of operational expenditure. The observed deficiencies and proposed suggestions in order for improving the quality is set out in Table 1.

Table.1 Human Resource Development in Agricultural Education and Research

Observed Deficiencies	Suggestions for Improvement
Falling educational standards	a. Make ICAR accreditation compulsory within a time frame b. Avoid inbreeding, opt for continuous curriculum changes and closer monitoring of quality standards by ICAR through well designed mechanisms to have a minimum national standard.
Poor facilities (building, library, labs, etc.)	More allocation under ICAR development grant for infrastructure development; achieving adequate infra-structural growth and maintenance in each college / university. SAU Management Board must monitor the allocation for infrastructure under State government funding
Inbreeding	Institutions should develop linkages with other leading institutions and industries both within and outside the country on a regular basis on research and training. The present system of reserving 10-25 per cent of seats for students from other states must be continued.
Lack of updating by scientists of ICAR - SAU system	Scientists should be encouraged to get themselves trained / updated in the new developments in basic sciences and cutting edge sciences through centers of excellence, sabbatical, and visiting scientists schemes, overseas fellowships, etc.
Inadequacy of skill to solve field problems and entrepreneurship among the graduates of ICAR-SAU and people who seek to become agri-entrepreneurs.	Emphasis to be given for producing graduates as job providers not as job seekers, through RAWE, industrial tie-up programme, vocationalization schemes covering students who are unable to pursue higher education.
Poor governance	Improve governance through prioritization, monitoring and evaluation of all activities (education, research and extension education), reform administration including personal policies, financial management system, student counseling and placement, resource generation for sustainability, leadership development, etc.
Absence of synergy across ICAR-SAU and other institutions	Develop information networking on exchange of educational materials, research materials, library resources.

In-sufficient knowledge on modern agriculture among people who are for and in agriculture	Open distance education and short-term training for development officers in agriculture and other allied departments, school drop outs, agri-inputs dealers, agro-processors, exporters and marketmen etc. on current trends in agriculture.
ICAR-SAU scientists ignorance on relevance of agrl. education, and research to socio-economic issues.	Social sciences research must be strengthened including training of social scientists of ICAR-SAU on policy analysis, policy interfacing and supporting agro-biological scientists in research problem diagnosis and prioritization.

Launching national level programmes such as Agricultural Human Resource Development project (AHRDP) is a real need to improve the educational system in agriculture and meet its future challenges. So far, only SAUs in three States participated (Tamil Nadu, Haryana and Andhra Pradesh) in AHRDP and the scheme must be extended to other states. AHRDP will prepare the SAUs for getting of accreditation by ICAR, syllabus reform, faculty improvement, upgrading and modernization of the laboratory facilities, farms, libraries, hostels, communication systems and other ancillary facilities. Similarly National Agricultural Technology Project (NATP) has achieved to bridge critical gaps of technology generation, assessment, refinement and transfer and to enhance ICAR-SAU institutions capability to meet future challenges on research and development fronts. Such kind of nation-wide programmes will offer enormous support to accelerate growth in agriculture.

7. Multiple Objectives and Priority Setting

Investment in agricultural science and technology (S&T) has been critically important to past agricultural growth performance and is likely to be even more important for achieving Millennium Development Goals of halving poverty and hunger by 2015. However, there arises a question, "what weights need to be assigned to growth promoting parameters, equity promoting parameters, suitable natural resource management parameters, trade parameters and food-nutrition security parameters in research priority setting for different agro-climatic zones.

Investments in agricultural S&T underpin innovation needed to promote economic / agricultural growth and enhance competitiveness by reducing production costs. Promoting agricultural growth has major impacts on poverty reduction. International Food Policy Research Institute (IFPRI) studies on impacts of public investment in India and China show agricultural R&D to have higher impacts on poverty reduction than do most other public investments, behind only in education in China and rural roads in India (Fan *et al*., 1999).

Priorities in investment on agricultural R&D must also ensure that benefits must reach all categories of farmers. Small, marginal and poor farmers and agricultural labourers must not be left behind. In the early phase of green revolution in Asia, it was reported that small farmers were not benefited. Similarly, research resource allocation must take care of crops grown in dry farming, backward and tribal regions so as to avoid growth imbalance between irrigated and dryland agriculture.

Degradation of natural resources and public concern over environmental issues are shifting research priorities and funding toward broader issues, many global in nature such as land, water, forests, and biodiversify, and safer agricultural products. There are also increasing opportunities for agriculture to provide environmental services through carbon farming and conserving biodiversity. Investment in Natural Resource Management (NRM) assumes more importance for the future.

Improved technology and information, especially at the post harvest stage, is essential to help farmers to orient to market needs, lower costs, improve product quality and food safety, meet more demanding grade and standard requirements, and diversity to higher value and niche products. Non-traditional exports (for example, horticulture products, cut flowers and organic foods) offer potential for major increases in rural employment and income, but frequently require substantial research and an entirely new base of knowledge and skills not generally available in the country.

Green revolution's core agenda was to improve the food security because many Asian and African countries were experiencing food shortages. Given the population growth, particularly in the developing world, sustaining food and nutritional security will continue to be an important objective of growth. Investment in new areas such as breaking yield barriers in food grains and evolving crops with more protein and micronutrient contents through genetic engineering, biotechnology, most efficient agronomic practices need more research investment (Annexure 19).

In this context of competing priorities, the weights to be given will certainly vary from country to country and region to region. For India with a population size of more than one billion, providing food and nutritional security and preserving and more efficient use of natural resources must receive more weights than other priorities. Poverty reduction is achievable through various development investments. And trade promotion certainly becomes last in the order. However, in-depth social science research must continue to analyse the implications of weights given to different research priorities and the results of such research has to help to alter the priorities as the nations progress. And assigning weights must be flexible overtime.

7.1. Investment Prioritization

Agricultural research, extension and education compete with other investment opportunities for scarce public resources. Availability of investible resources and politico-economic factors are more important for making resource allocation decisions. The variables which influence agricultural research, education and extension investment as evidenced through various studies are: agricultural GDP (expected to induce more research and extension), irrigation expansion, agricultural terms of trade, agricultural diversification, per capita government revenue (expected to have positive effect on research and extension), share of government expenditure on agriculture, proportion of rural population, rural literacy, technology spill-ineffects, etc. Models have been estimated for India considering above variables. In the first stage, this kind of objective approach be considered for identifying variables which positively influence the investment on agricultural research, education and extension. Within the investment made for agricultural research, education and extension, agricultural research and education largely go together handled by ICAR Institutes and SAUs in the public sector with a relatively a minor role for extension, which is primarily implemented by State Development Departments. It is the State Agricultural Ministry which decides how much for agricultural research and education and for extension. There is little objectivity involved in this resource allocation between research and education and extension. It is done by historical trends both by Centre and the States. It is important that statewise analysis of constraints and opportunities need to be taken up and resources between research and extension allocated based on real needs. The analyses also take into account both public and private sector investment.

7.2. Research Prioritization

One of the formidable tasks for agricultural research planners and policy makers is on how to allocate research resources among regions, commodities, research problems and often disciplines. Until recently, both in international arena and or in NARS, research priority setting on objective basis received little attention. In India, since the launch of National Agricultural Technology Project (NATP), more awareness has been created among policy makers and agricultural scientists with the leadership given by National Centre for Agricultural Economics and Policy Research of ICAR. A good amount of training has been imparted to hundreds of agricultural scientists in the country on 'Agricultural Research Priority Setting'. In recent years more literature has appeared on concept and methods of research priority setting in agriculture.

Five methods singly or in combination are adopted for carrying out research priority setting. The choice of the model is guided by the level of priority setting (macro or micro), availability of data, analytical skills and resources. The five methods are congruence (weighted criteria) model, economic surplus model / benefit cost analysis, mathematical programming, econometric models and simulation model. Each method has its own merits and demerits. The main thrust of research evaluation analysis is to compare a situation without research, against an alternative situation with research. Economic surplus model provides a relatively simple, flexible approach to specifying the value of research, by comparing the situations with and without it. It computes gains in production efficiency through reduction in per unit cost of output. This is used to estimate the benefits or economic surplus, as well as its distribution among producers and consumers.

Programming models rely on mathematical optimization to choose a research portfolio through maximizing a multiple objective function given the resource constraints of the system. They have the advantage of explicitly incorporating the budget, human resource and other constraints in the system. Like scoring models, they facilitate the inclusion of multiple objectives. If constructed in a multi-period format, they can identify how the research portfolio should change overtime. However, they require a great deal of analytical ability, data and time. Several variants of the basic multiple-objective, mathematical programming model are available for obtaining a weighted "optimal" solution or a set of feasible solutions that trade off the various objectives. The two basic means of solving this general model are: (a) to define and apply a set of decision makers' preferences or weights before optimization, so as to obtain a unique optimum solution, or (b) to generate a set of non-inferior solutions that illustrate the trade-offs among objectives rather than provide only a single optimum solution (the decision makers must choose then from a, sometimes large, set of possible solutions). In the latter approach, non-inferior solutions are generated without prior specification of preferences by parametric variation of either the weights on the objective function or constraints on the solution. This more generally adopted approach, of varying the weights or constraints, amounts to defining empirically the benefit transformation curve or surface which shows how the (maximum) value of the objective function varies with changes in activities (i.e. How the total research benefits vary with changes in combination of research programmes. The first approach amounts to specifying the slope of a particular indifference curve and the constraints, and then finding a point on the transformation curve.

Setting a need-based demand-driven research agenda has become essential in the current situation of resource crunch. Farmers who are the ultimate clients of research output face a large number of production related constraints. Identifying the technology needs of users and translating these needs into research programmes is an essential component of production system research. It will lead to emergence of clear and well-defined research themes to undertake more research. There is no single best method for identifying client constraints and research needs. A review of literature can also help to provide some insight about the existing constraints. Basically three methods are found to be most prevalent for identification of constraints. These are: (i) Rapid Rural Appraisal (RRA), (ii) Participatory Rural Appraisal (PRA) and (iii) Focused Group Meeting (FGM).

Yield gap is computed to understand the severity of constraints. Yield gap is defined as the difference between the potential yield and actual yield. The difference is explained by a number of constraints – biological, physical and socio-economic. All these constraints together account for the entire yield gap. Two types of yield gaps exist. Yield gap I is the difference between experiment station and on-farm experiment yields and yield gap II is the difference between yield attained in on-farm experiments and actual farm yield. The yield loss due to each constraint will be estimated to represent the severity of constraints. Steps involved are: (i) delineate the target domain using the scientific approaches and select the sample area, (ii) categorize the delineated zone in high, medium and low intensity zones and select the villages in equal proportion from each zone, (iii) conducting RRA/PRA in the selected villages, (iv) preparing list of all constraints including biotic, abiotic and socio-economic constraints, (v) estimating the severity of constraints through yield loss, (vi) obtain information on frequency of occurring a particular constraint and also on proportion affected, (vii) prioritize the production constraints on the basis of value loss.

The estimation of econometric models (statistical regression based models which incorporate economic theory) involve the collection of historical data on production, inputs, prices, past research expenditures etc. to statistically assess the contribution of research to changes in production of agricultural commodities. Numerous studies have estimated these models (production function, value-added function, profit function and supply-function) for expost evaluation of agricultural research. While the results of these studies have been used to justify additional research funds for particular commodities, no research system has so far systematically used the results of a comprehensive economic analysis for all its major commodities to help research priority setting. These models have the advantage of requiring little scientist's time. They may provide a more accurate assessment of the efficiency benefits of research than other approaches provided past, good historical data are available for the analysis, and the analyst has knowledge of econometrics. The disadvantages of these models are their inability to consider multiple goals, difficulty of providing information on priorities for research areas within commodities, the need for good historical data; and the skill required of the analyst.

Domestic Resource Cost-Ratio Technique essentially involves ranking of commodity programmes on the basis of comparative advantage of domestic production. The DRC ratios purport to tell us whether or not it will be in the national interest to produce a particular commodity. When the ratio is less than one, there is a comparative advantage and a case for high research priority for that commodity. When it becomes more than one, there is no comparative advantage and may indicate case for low research priority. This method also is suitable to priority setting at the national level for commodities. It is not useful for priority-setting in non-commodity research. It is also not useful for decisions on individual lines of research within commodity programmes. When a research system attaches much importance to self-sufficiency, the DRC ratios cannot be used to set research priorities.

Under the liberalized trade research impact is analysed under various situations like (i) small country assumption (importer / exporter) – with and without research spill over and (ii) large country assumption (importer / exporter) – with and without research spill over. In any country it is usual to find a range of trading environments for different agricultural commodities. For some commodities, the country will be a net importer, for others production will exceed domestic consumption requirements and net exports will occur. With yet other commodities transport costs or other factors may make trade unattractive, the country will consume all of domestic production and prices will be determined only by domestic production and consumption conditions. For traded commodities it is possible that the country's share of trade is so small that any changes in domestic conditions have a negligible effect on world prices. For other commodities this may not apply and changes due to research impacts might be expected to affect world prices. The latter may also occur if there are research spillover effects to other large producers who do provide a significant share of world trade. As well as trade in final commodity outputs, many countries also import or export the inputs used in agricultural production. Thus, questions regarding net import replacement or export enhancement may need to be considered. It is likely that non-traded final commodities may also use traded inputs. If so it may be important to consider research on both traded and non-traded commodities when considering these objectives.

With a small country and no research spillover environment, the world and domestic price will be unaffected by potential research on the commodity within the country. Large country assumption is that the country produces and imports or exports a substantial share of world production of a commodity; and/or if the research results produce technologies which, with adaptive research effort, are applicable in other countries and the combined output of all these countries represents a significant share of world output. In either or a combination of these circumstances the import or export parity price facing the country will change due to the impact of research. It is important to consider how this may influence the pre- and post-research import or export levels of the commodity. In most economies, several inputs used in the agricultural sector are traded, often imported. If import replacement is a research policy objective, then consideration of the value of imported inputs used may be required. Similarly, if the commodity is exported but uses significant quantities of imported inputs the change in the value of these inputs may be important. The possibility of an environment where inputs are traded introduces the need to consider non-traded as well as traded commodities. Even if the output is not traded internationally, some of the inputs used in production could be traded. If so, it is likely to be important to consider changes in the imported value of inputs resulting from research. Data to be required are gross value of current imports or exports, the change in the value of commodity imports or exports due to research, the change in the value of imported inputs due to the impact of research, and the expected gross national benefits from research and their distribution between producers and consumers in the country where research takes place.

Use of congruence model, for research priority setting is briefly discussed here. Often, the problem encountered in allocation is how to allocate resources across commodities and regions. Prioritization of commodities and regions involves calculation of an initial baseline matrix consisting of the value of output from different commodities in different regions. A composite baseline is then developed using the value of output (efficiency), number of poor people (equity) and arable land (sustainability), with equal weights for these three parameters. This step in allocation captures only extensity parameters. This construct can be improved by considering intensity parameters such as growth in AgGDP, per capita income, child malnutrition, extend of ground water withdrawal, per capita water availability etc. in the respective regions (Jha *et. al*., 1995). This modification with intensity parameters is to give priority to that region where the intensity of problem is more severe. Having selected the modifier, the next step is to decide the weight and the sign attached to each modifier and arrive at final base line (Mruthyunjaya, 2003).

The relative emphasis on different agro-ecoregions based on final base line varies considerably from the relative priority ranking based on value of production (VOP) alone. The shifts in relative emphasis among different agro-regions have to be translated in terms of priorities of commodities in every agro-ecoregion. The factor for adjustment for each agro-ecoregion, is the ratio of the final baseline and VOP. The adjusted VOP is used for arriving at commodity priorities in an agro-ecoregion or aggregate priorities for all the agro-ecoregions. This is the modified congruence model.

This model gives priorities by commodities and agro-ecoregions. This priority matrix can be used to arrive at different priority dimensions such as AER (sum over commodities by AERs), commodity priorities (sum over AERs by commodity) or commodity group priorities for the region (sum over commodities and AERs). The modified congruence analysis, which assumes constancy of relative shares of commodities or agro-ecoregions, can be a starting point for research prioritization. But the results need to be adjusted for expected changes arising from unfolding of growth opportunities, research capacity and challenges of globalisation.

Research priority mechanisms have to be institutionalized in various research centres in order to give importance to prioritize agriculture research considering commodities, regions, sustainability, poverty and equity. Agricultural research and institutional reforms should be geared up to address the challenges posed by increasing environmental problems like land degradation, chemicalization, water logging, salinity and alkalinity and weather fluctuations. Higher allocation to address these problems should be mandatory. Establishment of Priority setting, Monitoring and Evaluation (PME) cell in all the agricultural universities and training the manpower on the research prioritization are mandatory for judicious use of resources. ICAR institutes and SAUs, in a coordinated approach, must address the research problems without any duplication. In such cases available resources can be more judiciously used with a focus on major thematic areas of research. More allocation for conduct of training on IPR and patenting of inventions is mandatory for protecting the scientific discoveries and farmers.

8. Institutional reforms for effective extension

For SAUs, research and teaching are of higher priority. SAUs spent only 5 per cent of its expenditure on extension education (the corresponding figures are 17 per cent for administration, 33 per cent for academic and 45 per cent for research) and employed only 4.7 per cent of its manpower on extension units. With the current policy of creating one KVK for each district, many SAUs have established new KVKs with about 7.5 to 10 per cent of resources going for extension. The rest of the manpower was deployed in research (37.6 per cent), academics (40.4 per cent) and administration (17.3 per cent) (Rao and Muralidhar, 1994). There are clear indications that the funding for extension would also come from diverse sources. The public sector extension needs to make conscious efforts to learn from the on-going institutional experiments and should restructure itself with the necessary expertise and skills to meet the emerging demands of farmers for better services and to enhance its capacity in integrating information and expertise available with different organizations. Then only, the emerging diversity in funding and delivering extension could be better used to provide a number of useful services to farmers. To remain relevant and useful in the years to come, extension system has to strengthen its understanding on technology, markets, prices, demand and policies (Rasheed and van den Ban, 2000). Studies showed that how difficult it is for the public sector research and public sector extension to maintain effective linkages (Kaimowitz, 1991). Therefore, it is essential to develop an effective linkage between the public sector research and public sector extension for speedy dissemination of frontier technologies.

In the extension delivery system (Annexure 15) Producers' Cooperatives, Farmers Associations and Department of Agriculture (DoA) have a reasonably good technical man power - cultivator ratio- atleast one technical person for about 1332 farmers. With increasing costs of providing services and the government's unwillingness to fully support extension activities force many organizations in the public sector such as Department of Agriculture (DoA), research organizations (ICAR and SAUs) and training organizations (KVKs) to identify services that could generate resources. Considerable scope exists for initiating paid extension services in agriculture. DoA and other agencies in public sector should initiate problem solving consultancy services and need based training programmes, especially in on-food grain crops. Public sector should also set a policy framework for encouraging private agencies in field of extension activities. Opportunities for the successful integration of efforts of public agencies, private sector and farmers groups are emerging in some areas. The demand for paid services was more in non-food grain crops, especially, horticultural crops (fruits, vegetables, flowers and spices) and oil seeds. Thus considerable scope exists for initiating paid extension services in agriculture. Farmers' Associations and producers' co-operatives exists only for few crops / commodities. Initiating, sustaining and promoting farmers organizations should be a high priority for the public sector of this country. Involvement of NGOs and SHGs in extension delivery system is also crucial.

Notes

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[1] For historical review of growth of Indian NARES, see Suresh Pal and Alka Singh, 1997.

[2] TFP can be interpreted as a measure of change in output relative to a weighted combination of inputs, where the weights are factor shares. This can be defined as the ratio of aggregate output to aggregate input (Evenson *et al*, 1999). Sources of growth of TFP is due to technology, infrastructure-institution and other variables such as agro-climatic conditions.

[3] The proposed equation is:

$LnY_{jt} = \alpha_0 + \beta lnRD_{it} + \gamma ln\ CC_{jt} + lnI_{jt} + D_t + \Sigma_{jt}$

where, Y = Yield of crop (kg/ha)

RD = Agricultural research expenditure (Rs./ha)

CC = Cost of cultivation (Rs./ha)

I = Extent of area under irrigation (% of GIA to GCA)

D = Dummy for technological stagnation

The data pertaining to the year 1980-81 to 2001-02 were used to analyse the impact of agricultural research expenditure on cost reduction. In addition dummy variable for technological stagnation particularly during 1990s (1990s = 1, otherwise 0) was also included in the model.

[4] The details of index construction:

i. Income entitlement = Index of Agricultural GDP per capita
ii. Food security = Index of per capita food grains consumption

iii. Nutritional security = (1/4) index of per-capita egg consumption + (1/4) index of per capita milk consumption + (1/4) index of per-capita fruit consumption + (1/4) index of per-capita vegetable consumption.
iv. Employment guarantee = Index of agricultural labour force
v. Equity = Index of poverty ratio reduction
vi. Efficiency = (1/3) land productivity index + (1/3) irrigation use index + (1/3) index of fertilizer application per unit of land
vii. Sustainability = (1/2) water productivity + (1/3) index of bio-fertilizer use + (1/3) index of bio-pesticide use.

Composite Index was constructed with equal weights assigned to all criteria. The composite index was estimated as:

Composite index = (1/7) income index + (1/7) food security index + (1/7) nutritional security index + (1/7) employment guarantee index + (1/7) equity index + (1/7) efficiency index + (1/7) sustainability index.

[5] $\ln CI = \ln a + b \ln RD$
where,
CI – Composite Index
RD – Research and Development Expenditure on Agriculture

[6] Notes on budget discussions.

[7] Annual intake of students in various agricultural universities amount to 10049 for undergraduates, 5170 for Masters degree programme studies and 1544 for Ph.D. programme. (Source: Agricultural Research - DAIA Book, 2004, ICAR, New Delhi, 2004).

Annexure-1. Institutional Growth of ICAR

(No.)

Institutions	1960-70	1970-80	1980-90	1990-2000	2004
Deemed Universities	-	-	-	3	4
State Agricultural Universities	13	24	26	29	34
ICAR Institutes		26	-	41	45
National Research Centres	-	-	-	20	30
National Bureau	-	2	2	4	4
Krishi Vigyan Kendra	-	33	108	259	262
National Research Centre in Agriculture for Women	-	-	-	1	1
Project Directorates	-	-	-	-	10
All India Coordinated Research Projects	-	-	-	-	80
Trainers Training Centres	-	-	-	-	8
Operational Research Projects	-	-	-	-	400
Other schemes and Projects	-	-	-	-	26

Source: Sreenivasulu and Nandwana (2001).

Annexure-1A. Estimated Marginal Internal Rates of Return to Agricultural Research and Extension in India

Category / study	Year	Crop	Period	Estimated marginal internal rate of return (EMIRR) (%)
Evenson and Jha	1973		1953-71	40
Kahlon et al.	1977		1960-73	63
Evenson and McKinsey	1991		1958-83	65
Rosegrant and Evenson	1992			62
Tabor	1998		1956-87	58
Rosegrant and Evenson	1992			52
Rosegrant and Evenson	1992			50
Evenson and McKinsey	1991	Rice	1954-84	155
		Wheat	1954-84	51
		Jowar	1954-84	117
		Bajra	1954-84	107
		Maize	1954-84	94

Source: Tabor (1998); Evenson *et.al*. (1999)

Annexure-2. Impact of Research Expenditure on Agricultural Output

Variable	At current prices		At constant prices	
	Coefficient	SE	Coefficient	SE
Gross Cropped Area	2.58***	0.85	2.11***	0.59
Agricultural Labours	0.73**	0.35	0.33	0.23
Research Expenditure (t-2)	0.39**	0.17	0.24**	0.11
Constant	-26.12***	10.15	-18.82***	6.68
	R^2 = 0.96, Adjusted R^2 = 0.95		R^2= 0.94, Adjusted R^2= 0.93	

*** significant at 1 per cent level, ** significant at 5 per cent level;
Dependant variable: Agricultural GDP expressed in Rs. crores.
Equation is estimated in log-Linear form Source: Authors' estimation

Annexure-3. Research Induced Supply Shift in Important Crops

Variables	Rice	Wheat	Maize	Pulses	Oil seeds	Sugarcane	Cotton	FPI
Constant	9.07***	8.07***	6.50	8.96***	6.57***	10.19***	6.83***	1.03
Research Expenditure (t-2)	0.06	0.34***	0.14	-0.09	0.09	0.19*	0.28**	0.49***
Commodity Price (t-1)	0.30	0.27***	0.45	0.13*	0.41***	0.22***	0.16*	0.41**
R^2	0.22	0.94	0.32	0.35	0.88	0.91	0.79	0.88

*** significant at 1 per cent level, ** significant at 5 per cent level;
Dependent Variable: Output of Crops (in '000 tonnes). Equation is estimated in log-linear form
FPI: Food Grain Productivity Index
Source: Authors' estimation

Annexure 4. Coverage of HYVs of Major Crops

Crops	Area under HYVs (000 ha)		
	1970s	1980s	1990s
Rice	11861 (30.70)	22260 (54.82)	31009 (71.76)
Wheat	12145 (60.40)	18760 (80.50)	22190 (89.37)
Jowar	1841 (11.32)	5274 (33.25)	7224 (58.21)
Bajra	2556 (21.82)	4918 (44.54)	5545 (55.28)
Maize	960 (16.43)	1979 (33.88)	3102 (51.60)
Total Cereals	29215 (28.83)	53191 (51.33)	68825 (68.37)

(Figures in the parentheses are percentage to total area)
1970s: 1970-71 to 1979-80 1980s: 1980-81 to 1989-90 1990s: 1990-91 to 2002-2003
Source: Authors' estimation

Annexure-4A. Coverage of HYVs of Rice

States	Area under HYVs (000 ha)			
	1970s	1980s	1990s	Overall
Assam	367.35 (17.25)	974.45 (41.83)	1169.48 (46.64)	837.09 (36.05)
Andhra Pradesh	1899.2 (54.28)	3148.3 (84.67)	3338.3 (86.95)	2795.3 (75.85)
Bihar	838.75 (15.93)	2041.40 (39.34)	2788.14 (56.39)	1889.43 (36.81)
Karnataka	133.40 (29.53)	359.60 (71.28)	521.58 (85.83)	338.19 (64.87)
Gujarat	177.4 (52.30)	438.2 (80.37)	516.2 (62.25)	377.3 (66.05)
Haryana	167.15 (68.48)	243.40 (90.55)	221.36 (81.68)	210.64 (80.61)
Jammu and Kashmir	266.55 (31.17)	317.80 (45.67)	195.23 (41.99)	259.86 (38.67)

Kerala	398.9 (35.81)	838.1 (72.94)	1074.6 (80.90)	770.5 (64.37)
Maharastra	546.9 (39.01)	1061.2 (70.52)	1270.9 (83.29)	959.6 (64.94)
Madhya Pradesh	926.0 (20.08)	1816.0 (36.85)	3213.4 (60.65)	1985.1 (40.14)
Orissa	510.05 (11.40)	1647.40 (38.68)	2881.84 (64.11)	1679.76 (38.09)
Punjab	567.6 (84.77)	1490.3 (94.22)	2022.9 (90.54)	1337.4 (89.45)
Uttar Pradesh	1609.1 (34.24)	3270.9 (61.96)	4961.2 (88.29)	3280.4 (63.09)
Tamil Nadu	2160.7 (81.65)	1966.6 (91.35)	2088.2 (96.60)	2071.8 (89.29)
West Bengal	1055.0 (20.53)	2198.3 (41.76)	4164.1 (71.08)	2472.4 (45.62)
India	11860.9 (30.70)	22259.5 (54.82)	31008.7 (71.76)	21709.7 (53.19)

(Figures in parentheses denote percentage to area under rice)
1970s: 1970-71 to 1979-80 1980s: 1980-81 to 1989-90 1990s: 1990-91 to 2002-2003
Source: Compiled from various sources like Agricultural Statistics at a Glance and Agriculture in Brief

Annexure 5. Population Below Poverty Line, All India

	Year		
	1983	1993-94	1999-00
Rural			
No. of Persons (Lakh)	2519.56	2440.31	1932.43
% of persons	45.65	37.27	27.09
Poverty Line (Rs.)*	89.50	205.84	327.56
Urban			
No. of Persons (Lakh)	709.40	763.37	670.07
% of persons	40.79	32.36	23.62
Poverty Line (Rs.)	115.65	281.35	454.11
Combined			
No. of Persons (Lakh)	3228.97	3203.68	2602.50
% of persons	44.48	35.97	26.10

Source: Agricultural Statistics at a Glance, 2002;
* - Percapita per month

Annexure 5A. Fall in Poverty Levels

(Per cent / annum)

Year	1970s		1990s		1970-71 to 1999-00	
	Mean	CGR	Mean	CGR	Mean	CGR
Per capita AgGDP (Current Rs)	1025	8.89	4649	12.59	2112	10.48
Per capita AgGDP (Constant Rs)	907	0.80	1101	2.15	965	1.16
Rural Population (000')	534868	1.77	682198	1.37	579067	1.70
Rural Population (BPL 000')	256484	-0.63	227170	-3.01	247690	-0.81
Rural Population (BPL %)	49	-2.35	33	-4.32	44	-2.47
Agrl. Production (Index)	106	2.84	164	2.37	124	2.94
Food Articles (WPI)	104	7.97	345	8.39	176	8.59
Agrl. Labour (CPI-General)	75	6.84	233	8.49	122	7.79
Agrl. Labour (CPI-Food)	76	6.97	241	7.61	126	7.91

CGR - Compound Growth Rate; WPI - Whole Price Index; CPI - Consumer Price Index
1970s: 1970-71 to 1979-80 1990s: 1990-91 to 1999-2000
Source: Authors' estimation

Annexure 6 . Impact of Public Investment on Agriculture on Poverty Reduction

(percent)

Expenditure variable	Elasticities		Marginal impact of spending Rs 100 billion at 1993 prices		Number of poor reduced/Rs million spent
	Poverty	TFP	Poverty	TFP	
R&D	–0.065*	0.296*	–0.48*	6.98*	91.4*
Irrigation	–0.007	0.034*	–0.04	0.56*	7.4

Roads	–0.066*	0.072*	–0.87*	3.03*	165.0*
Education	–0.054*	0.045*	–0.17*	0.43*	31.7*
Power	–0.002	0.0007	–0.015	0.02	2.9
Soil and water	–0.0004	0	–0.035*	0	6.7*
Rural development	–0.019*	n.a.	–0.15*	n.a.	27.8*
Health	–0.0007	n.a.	–0.02	n.a.	4.0

Source: Fan, *et. al*., (1999)
Note: TFP is total factor productivity. n.a. is not available.
* Significant at the 5 per cent level.

Annexure 7. Agricultural Growth and Poverty – Weakening of Trickle Down Mechanism*

Year	Intercept	Per capita AgGDP	t value	R^2
1972-73	89.462	-0.090	-5.241	0.696
1977-78	83.113	-0.069	-4.121	0.586
1983-84	68.333	-0.055	-3.809	0.547
1986-87	52.330	-0.031	-3.281	0.473
1999-00	32.286	-0.003	-3.821	0.422

Source: Ramasamy (2004); PCSGDP - Per capita State Gross Domestic Product
Dependent variable - poverty levels in per cent
* States constitute sample

Annexure-8. Public Sector Expenditure - Plan-Wise

(Rs. in Crores)

Five Year Plan	Agriculture and Allied Sectors *		Total Expenditure		Percentage of Agriculture and Allied to Total	
	Plan Outlay	Actual Expenditure	Plan Outlay	Actual Expenditure	Plan Outlay	Actual Expenditure
First Plan	354	290	2378	1960	14.9	14.8
Second Plan	510	549	4500	4672	11.3	11.7
Third Plan	1086	1089	7500	8577	14.5	12.7
Annual Plan	1037	1107	6665	6625	15.6	16.7
Fourth Plan	2728	2320	15902	15779	17.2	14.7
Fifth Plan	4766	4865	39322	39426	12.1	12.3
Annual Plan**	1815	1996	12601	12176	14.4	16.4
Sixth Plan	l2539	15201	97500	109292	12.9	13.9
Seventh Plan	22233	31509	180000	21870	12.4	14.4
Eighth Plan	63642	70146	434100	4855456	14.7	14.4
Ninth Plan	42462	N.A.	859200	N.A.	4.9	N.A.
Tenth Plan	50668	NA	398890	NA	5.2	NA

* - Includes Animal Husbandry & Dairy, Research & Education, Forestry & Wild life, Plantation, Agricultural Marketing & Rural Godowns, Food Storage & Warehousing, Rural Development, Cooperation, Special Area Programmes, etc.
N.A.-Not Available Source: Planning Commission, GOI
** Relates to 1979-80.

Annexure-9. Public Expenditure on Agricultural Research and Development and its Intensity

(Rs. in crores)

Particulars	Current prices			1980-81 prices		
	1970s	1980s	1990s	1970s	1980s	1990s
GDP at factor cost	58588	200825	917095	102452	156161	322284
AgGDP at factor cost	25699	71466	257918	46027	55821	92409
R&D public expenditure	257	963	2925	434	741	1086
R&D as % of GDP	0.004	0.005	0.003	0.004	0.005	0.003
Public expenditure on R&D as % of AgGDP	0.01	0.013	0.011	0.009	0.013	0.012

Growth rates						
GDP	12.60	12.32	19.84	3.45	5.41	10.62
AgGDP	8.68	11.27	13.94	0.09	4.43	5.73
Public expenditure R&D	19.21	14.61	8.48	9.51	7.56	0.65

Source: Authors' estimation
1970s: 1970-71 to 1979-80 1980s: 1980-81 to 1989-90 1990s: 1990-91 to 2002-2003

Annexure-10. Impact of Agricultural Research Expenditure on Yield of Crops
(Autocorrelation adjusted coefficients)

Y = log yield

Crops	Intercept	RD#	Unit cost	Irrigation	D_{TECH}
Rice	3.05* (1.80)	0.32*** (3.64)	-0.14 (-1.21)	1.37* (2.03)	0.03 (0.57)
Wheat	4.48* (1.83)	0.19* (2.00)	0.12* (1.88)	0.48 (0.76)	0.01 (0.18)
Groundnut	3.99** (2.29)	0.01 (0.43)	0.21 (1.13)	0.32 (0.71)	-0.17 (-1.15)
Sugarcane	9.70*** (5.20)	0.18*** (3.02)	0.03 (1.01)	0.11 (0.23)	0.02 (1.11)
Cotton	8.05** (2.62)	0.77*** (3.21)	0.03 (0.25)	-1.33 (-1.19)	-0.33 (-0.22)

(Figures in parentheses denote t value)
Research Expenditure of current period for wheat and sugarcane
Research Expenditure lagged by one year for rice and groundnut
Research Expenditure lagged by two years for cotton
Unit cost – Cost of cultivation/ha; Irrigation – Proportion of GIA to GCA; D_{TECH} – Dummy for technological stagnation
*** significant at 1 per cent level
** significant at 5 per cent level
* significant at 10 per cent level

Annexure-11. Reduction of Average Cost through Output Increase

Years	Scenario I*					Scenario II**				
	Paddy	Wheat	Groundnut	Sugarcane	Cotton	Paddy	Wheat	Groundnut	Sugarcane	Cotton
2002-03	1.58	0.94	0.08	0.90	3.70	3.21	1.91	0.08	1.80	7.94
2003-04	1.60	0.96	0.00	0.90	4.08	3.20	1.87	0.08	1.78	7.35
2004-05	1.63	0.95	0.08	0.90	3.92	3.20	1.91	0.08	1.80	7.76
2005-06	1.60	0.94	0.00	0.90	3.77	3.18	1.91	0.17	1.80	7.63

* 5% annual increase in Research Expenditure
** 10% annual increase in Research Expenditure

Annexure 12. Impact of Agricultural Research and Development Expenditure on Economic Welfare

Y = log of composite index

Particulars	Co-efficients	t-value
Intercept	3.206***	18.94
R&D Expenditure	0.38***	9.76
R Square	0.87	

*** significant at 1 per cent level

Annexure 12A. Composite Index of Impact of Agricultural Research

Years	INCOME	FOOD SEC	NUTR SEC	EMPL	EQUITY	EFFICIENCY	SUSTA	Composite Index
1970-71	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1971-72	94.62	99.42	99.85	102.00	102.58	108.05	98.99	100.79
1972-73	92.73	89.93	99.60	104.00	105.30	113.97	95.63	100.17
1973-74	100.27	96.25	99.54	106.00	108.13	110.95	97.96	102.73
1974-75	85.73	86.50	99.47	108.00	111.24	112.12	96.34	99.91
1975-76	83.89	90.51	100.50	110.00	114.45	111.05	99.85	101.46
1976-77	82.13	91.64	100.94	112.00	117.74	122.12	96.75	103.33
1977-78	91.23	99.83	101.52	114.00	114.03	130.07	100.09	107.25

1978-79	91.25	101.64	102.18	114.41	117.32	139.08	100.40	109.47
1979-80	78.35	87.54	101.82	117.97	120.70	153.32	94.61	107.76
1980-81	83.36	97.01	102.09	159.14	124.17	148.29	98.20	116.04
1981-82	83.62	97.08	102.72	160.98	127.75	151.38	99.73	117.61
1982-83	82.32	93.22	104.72	163.49	131.43	159.65	97.78	118.94
1983-84	90.64	102.28	108.54	165.71	132.64	166.16	101.19	123.88
1984-85	88.28	96.72	111.30	165.99	133.88	176.43	100.31	124.70
1985-86	88.54	101.86	116.95	166.18	135.12	179.35	100.10	126.87
1986-87	86.81	100.51	118.08	166.50	136.37	186.06	98.26	127.51
1987-88	87.91	95.48	114.50	166.96	154.86	191.40	97.67	129.83
1988-89	99.49	105.25	117.47	167.20	156.30	196.86	103.57	135.16
1989-90	99.97	100.81	120.57	167.36	157.75	201.34	103.96	135.97
1990-91	106.15	108.81	122.51	167.08	159.22	206.09	105.10	139.28
1991-92	108.49	100.00	125.28	175.42	160.70	210.57	104.09	140.65
1992-93	108.60	99.00	130.24	185.97	162.19	201.59	105.39	141.85
1993-94	123.27	100.51	133.93	188.97	162.47	200.17	133.95	149.04
1994-95	124.34	105.70	137.14	192.58	171.74	205.40	178.77	159.38
1995-96	123.54	101.37	139.05	187.48	181.55	204.46	204.39	163.12
1996-97	140.05	107.32	141.41	190.98	191.91	199.92	215.97	169.65
1997-98	140.03	95.35	148.22	194.44	202.86	222.28	231.82	176.43
1998-99	149.91	99.34	152.82	188.24	214.44	232.94	256.31	184.86
1999-00	152.97	96.93	153.02	186.80	223.52	245.62	334.55	199.06

Annexure-13. Public Expenditure on Research and Education and Its Intensity

Indicator	1960-62	1970-72	1980-82	1992-94	2001-02
1. Investment at current prices (Rs. million)	142	409	1858	9617	13890
2. Ratio of investment to Ag GDP (%)	0.21	0.23	0.39	0.49	0.32
3. Investment per hectare of GCA (Rs.)	0.93	2.47	10.49	51.85	70.87
4. Number of scientists	*	6009	14766	22249	33020
5. Investments/Scientist (000 Rs.)	*	*	*	432.27	420.65
6. Area/Scientists (000 ha of GCA)	*	*	*	8.34	5.90

Annexure 14. Expenditure on Agricultural Research and Development - Statewise

(Rs. in million)

State	Total	State	ICAR	Other Sources	NSDP	Share of R&D to NSDP (%)
Andhra Pradesh	1199.11	811.43	128.25	259.43	75432	0.10
	(100)	(68.29)	(10.51)	(21.19)		
Assam	439.04	335.07	78.97	25.00	21797	0.17
	(100)	(78.18)	(15.44)	(6.37)		
Bihar	493.10	382.70	84.89	25.53	43037	0.08
	(100)	(77.91)	(16.92)	(5.17)		
Gujarat	1025.54	850.97	120.85	53.73	80849	0.12
	(100)	(83.15)	(11.44)	(5.41)		
Haryana	867.30	680.85	151.05	35.40	36612	0.21
	(100)	(79.72)	(16.24)	(4.04)		
Himachal Pradesh	536.02	377.83	86.74	71.45	6391	0.55
	(100)	(70.79)	(17.04)	(12.16)		
Jammu Kashmir	252.71	221.22	30.96	0.53	7826	0.23
	(100)	(87.42)	(12.26)	(0.32)		
Karnataka	959.68	764.73	132.07	62.89	55507	0.11
	(100)	(80.26)	(13.27)	(6.47)		
Kerala	610.02	516.91	65. 27	27.84	49816	0.11
	(100)	(84.64)	(10.45)	(4.91)		
Madhya Pradesh	730.15	484.56	165.81	29.78	59630	0.09
	(100)	(64.49)	(22.99)	(3.82)		
Maharashtra	1931.68	1649.69	240.61	41.39	120722	0.08
	(100)	(86.39)	(11.34)	(2.27)		

Manipur	139.14 (100)	-	138.37 (98.85)	0.77 (1.15)	2117	0.42
Orissa	3531.16 (100)	2108.03 (60.20)	1025.32 (27.51)	397.82 (12.29)	22580	0.76
Punjab	1013.95 (100)	778.82 (76.84)	171.21 (16.10)	63.93 (7.06)	36554	0.19
Rajasthan	583.15 (100)	342.24 (59.32)	131.99 (24.51)	108.93 (16.16)	58593	0.10
Tamil Nadu	1240.72 (100)	935.81 (75.97)	174.03 (13.38)	130.89 (10.66)	99959	0.09
Uttar Pradesh	365.34 (100)	280.40 (75.66)	70.08 (20.39)	14.85 (3.94)	111616	0.03
Uttranchal	587.47 (100)	479.49 (84.09)	87.67 (12.78)	20.31 (3.13)	76610	-
West Bengal	470.84 (100)	357.88 (77.51)	63.75 (13.66)	49.21 (8.83)	75432	0.04

(Figures in parentheses are percentage to total)
Figures are six years averages (1996-97 to 2001-02)
Source: Compiled from the issues of Economic Survey and ICAR Annual Reports

Annexure-15. Performance Indicators of Extension Organizations (Average)

Organization	Extension expenditure (Rs./ha)			Contact intensity (hr / target population)	Technical manpower: cultivator ratio
	Total	Total salary	Extension		
Department of Agriculture	44.94	4.57	-	0.40	1:133
Directorate of Extension (SAUs)	0.74	-	-	0.01	1:635
Krishi Vigyan Kendra	5.58	4.21	-	0.09	1:542
Farmers Associations	-	-	46.97	3.01	1:108
Producers' Co-operatives	-	-	34.10	1.96	1:928
Research Institutes	-	-	0.24	-	-
Seed companies	-	-	0.53	0.002	1:578
Fertilizer companies	-	-	0.47	0.014	1:541
NGOs	18.59	-	-	0.49	1:138
Consultancy services	-	-	-	0.013	1:965
Commodity boards	824.2*	-	-	0.57	1:287
Marketing boards	0.19	-	-	0.002	1:492
Media - AIR	0.15	-	-	-	-
Media - Print	1.73	-	-	-	-

* A good amount of this goes as subsidies and administrative expenses
Source : Sulaiman Rasheed V and V.V. Sadamate (2000).

Annexure 16. Turnover of Key Indian Seed Players and Export of Seeds During the Year 2000

Seed Players	Turnover (Rs. in million)
Mahyco	1000 (19.69)
HLL	700 (13.78)
Proagro	600 (11.81)
Namdhari seeds	500 (9.84)
Ankur	400 (7.89)
Others	1180 (37.01)
Total	5080 (100)
India's seed exports	Value (Rs in crores)
Vegetable and flower seeds	80 (80.00)
Field crop seeds	20 (20.00)
Total	100 (100.00)

(Figures in parentheses denote percentage to total)
Source: Principles of Seed Production and Quality Control, 2003,
Bhaskaran, *et. al*., Kaiser Graphics Limited

Annexure 17. Indian Private R&D agriculture, 1984-85 to 1992-93 (Rs. millions)

Industries	1984-85	1988-89	1992-93
Seed	79	na	130
Ag. machinery	84	51	38
Fertilizer	25	97	52
Pesticide	193	248	281
Veterinary Pharmaceutical	23	37	44
Sugar	23	92	52
Food processing	33	296	213

Source : Mruthyunjaya and Ranjitha, 1998.

Annexure 18. Expenditure on Research and Development by major Scientific Agencies under the Central Government

(Million Rs.)

Agency	Research and Development Expenditure				
	1994-95	1995-96	1996-97	1997-98	1998-99
Council of Scientific and Industrial Research	3564 (9.17)	4117 (9.52)	4440 (9.52)	5641 (9.91)	7133 (9.87)
Defence Research and Development Organization	12460 (32.05)	13954 (32.26)	14357 (30.79)	19510 (34.26)	23002 (31.84)
Department of Atomic Energy	4452 (11.45)	4866 (11.25)	5299 (11.36)	6926 (12.16)	8367 (11.58)
Department of Bio-technology	661 (1.70)	738 (1.71)	743 (1.59)	771 (1.35)	945 (1.31)
Department of Electronics	332 (0.85)	364 (0.84)	435 (0.93)	470 (0.83)	621 (0.86)
Department of Non-conventional Sources of Energy	92* (0.24)	70* (0.16)	46 (0.10)	58 (0.10)	90 (0.12)
Department of Ocean Development	462 (1.19)	456 (1.05)	506 (1.09)	807 (1.42)	848 (1.17)
Department of Science and Technology	2038 (5.24)	2237 (5.17)	2271 (4.87)	2732 (4.80)	2990 (4.14)
Department of Space	7591 (19.52)	9179 (21.22)	10653 (22.84)	10505 (18.45)	15155 (20.98)
Indian Council of Agricultural Research	4350 (11.19)	4324 (10.00)	4715 (10.11)	5820 (10.22)	8440 (11.68)
Indian Council of Medical Research	482 (1.24)	506 (1.17)	536 (1.15)	680 (1.19)	863 (1.19)
Ministry of Environment and Forest	2398 (6.17)	2446 (5.65)	2634 (5.65)	3025 (5.31)	3780 (5.23)
Total	38882 (100)	43257 (100)	46634 (100)	56946 (100)	72234 (100)

Note: 1. Not including Public Sector Research and Development Expenditure

2. * Plan expenditure

Source: Research and Development Statistics, 2000-01, Department of Science and Technology, New Delhi

Annexure 19. Sectoral Outlay and Expenditure of ICAR*

(Rs. in million)

Sector	Expenditure Allocation				
	1997-98	1998-99	1999-00	2000-01	2001-02
Crop Science	690.50 (20.91)	875.32 (20.62)	969.30 (21.26)	1014.30 (19.64)	1150.00 (16.8)
Horticulture	295.00 (8.93)	420.64 (9.91)	415.91 (9.12)	436.00 (8.44)	500.00 (7.3)
Natural Resource Management	354.40 (10.73)	481.96 (11.35)	453.99 (4.35)	466.90 (9.04)	600.00 (8.8)
Agricultural Engineering	139.40 (4.22)	193.25 (4.55)	198.37 (9.20)	196.50 (3.80)	250.00 (3.6)
Animal Science	303.20 (9.18)	394.26 (9.29)	419.22 (4.63)	491.20 (9.51)	600.00 (8.8)
Fisheries	190.00 (5.75)	205.53 (4.84)	210.91 (0.64)	237.40 (4.60)	300.00 (4.4)
Agricultural Statistics & Economics	15.00 (0.45)	19.74 (0.46)	28.96 (0.63)	9.40 (0.18)	40.00 (0.6)
Agricultural Extension	400.00 (12.11)	468.57 (11.04)	511.20 (13.99)	620.80 (12.02)	900.00 (13.1)
Agricultural Education	303.00 (9.18)	467.41 (11.01)	637.77 (13.0)	637.90 (12.35)	800.00 (11.7)
World Bank Project / Foreign Aided Projects	361.70 (10.95)	481.82 (11.35)	595.68 (7.00)	1001.80 (19.39)	1550.00 (22.6)
Management and Information Services	244.50 (7.41)	232.18 (5.47)	108.70 (2.38)	48.20 (0.93)	100.00 (1.5)
Mini Mission	-	-	-	-	50.00 (0.7)

DARE	5.00 (0.15)	4.52 (0.11)	8.44 (0.19)	5.00 (0.10)	6.00 (0.1)
Total	3,301.70 (100)	4245.20 (100)	4558.45 (100)	5165.40 (100)	6846.00 (100)

(Figures in the parenthesis are percentage to total)
Note: The Foreign aided component is included in the respective subject matter division.

Source: ICAR Budget Books, 1997-98, 1998-99, 1999-2000, 2000-2001 and 2001-2002, Indian Council of Agricultural Research, New Delhi.

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