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Agricultural Research and Extension in India: Reflections on the Reality and a Roadmap for Renaissance*

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*The first lesson of economics is scarcity...The first lesson of politics is to disregard
the first lesson of economics.*

— Thomas Sowell

I

INTRODUCTION

Populations and demand for food continue to increase worldwide, but growth in agricultural productivity is slowing in many countries including India. As the world population is projected to surpass 9.0 billion by 2050, the world agriculture is currently facing serious challenges due to increasing demand for and limited or reduced supply of land and water resources. Climate change, increasing demographic pressures on resources, plateauing of crop yields in many parts of the world, and increasing volatility in food prices are some of the major concerns to be addressed by agricultural research in the foreseeable future. There is a compelling need to deploy more and more modern bioscience and physical science knowledge to develop new crop varieties and technologies to accelerate agricultural production without harming the agro-ecosystem. Uncertainties associated with and skepticism towards the health, ecological, and socio-economic impacts of modern plant biotechnology contribute for intense opposition to this technology. In addition to responding to natural resource constraints facing agricultural production, and the financial and human resource constraints facing agricultural research, the national agricultural research and extension systems have to confront and address the issues raised by the opponents of biotechnology, and proponents of traditional agricultural production methods ranging from organic agriculture to natural farming methods.

The broad changes influencing the earth's ecosystem and human species in the 21st century have innumerable, interconnected implications for agriculture and food security. Some interactions of socio-economic changes with biophysical and technological changes seem clear from this vantage point, while others will surely

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catch us by surprise. It seems certain that it will be necessary to produce a lot more food on the same or probably less amount of land with less water and less labour. It also seems certain that over the long run the society will demand similar environmental standards from agriculture as it demands from other sectors. This means that agriculture has to become more ecosystem-friendly and more sustainable than it is at present. But this has to take place without compromising the growth in agricultural productivity that is required to ensure and sustain food and livelihood security. The overarching concerns of nutritional and livelihood security, poverty alleviation, farm profitability, gender equity, ecology and environment, competitiveness in terms of cost and quality will continue to be the major research issues for the National Agricultural Research System. Therefore, agricultural research system has to undergo substantial transformation both in terms of its content and the form in order to address the critical challenges mentioned above. This paper is a broad-based attempt to offer a comprehensive overview of the present problems in agricultural research and extension systems, and provide plausible roadmap to put them in a new growth path by reviving its old glory. Starting with an overview of the trends in agricultural research investments, the paper discusses the policy and institutional issues, organisational and management problems, human resource development for agricultural research, and issues in agricultural extension. In the last section of the paper, a broad set of suggestions are offered for the future in order to make agricultural research and extension systems more vibrant, productive and efficient.

II

AGRICULTURAL RESEARCH INVESTMENTS: RATIONALE AND ISSUES

Much of the conventional agricultural research programmes fall under the category of impure public goods and hence national and local governments have invested heavily in public agricultural research, even though private sector plays a key role in areas where the research output could be patented and hence treated almost as private goods. Like every other sector of the economy where knowledge is the driving force, agriculture has to embrace a similar path too. New innovations and modern technologies are the prime movers of agricultural productivity and growth. The economic impacts of agricultural research are manifold. As the driver of agricultural productivity, production and profitability, agricultural research has strong correlation with food and nutritional security, rural employment and income, and environmental sustainability, and also the internal peace and security of nations. Economic studies on agricultural research impacts started with the seminal work of Zvi Griliches in his 1964 paper on “research expenditures, education, and the aggregate agricultural production function”, published in *American Economic Review*, followed by a more elaborate study by Robert Evenson in his doctoral research entitled Contributions of Agricultural Research and Extension to

Agricultural Productivity at the University of Chicago in 1968. Several methodological and data issues notwithstanding, this body of economic research across several countries, has firmly and unequivocally established that the rate of returns to investments in agricultural research and development is significant and higher than that from other comparable investment options.

Returns on public investment in agricultural research are consistently high. A meta-analysis by the International Food Policy Research Institute, using more than 1,000 studies and analyses across the agricultural research spectrum show returns of between 44 per cent – 80 per cent in investment. The World Bank's *World Development Report 2008* found an average rate of return on agricultural R&D and extension in the developing world of 43 per cent, based on nearly 700 published studies. Public investment in agricultural research is extremely valuable, providing more than half of the agricultural productivity growth. 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 agrobiological research, a vibrant public research system should continue. Public research should concentrate on developing cost-effective technologies with quality trait in order to enhance the competitiveness of agricultural products both in the domestic and international markets. A strong public research system at both national and international levels are needed not only to provide technological support directly to the farming community, but also to effectively compete with the powerful private R and D system that is built primarily on profit-motive and control over the technological outputs rather than reaching out to the poor farmers and ensuring social welfare. The public research system should be an effective force in counteracting the adverse impacts and/or skewed distribution of impacts caused by increasing private control over technological knowhow, IPR system and the market-oriented strategic research programme of the powerful private sector. Significant public research expenditures are needed to accelerate and sustain agricultural productivity growth, while at the same time providing research support to help sound public- and private-sector collaborations on a multitude of evolving food system issues including food security, food safety and nutritional issues. Public agricultural research system should exchange knowledge with private sector with an assurance that the knowledge is protected from patenting by the private sector. Stronger IPR legislation and enforcement will enable the farmers to access the most advanced relevant technologies because such partnership help the private sector to supply better and relevant technologies in time at lower cost on account of competition.

Global Trends in Agricultural R and D Spending

Although public research investments constitute a major share in total agriculture R and D investments, the share of public sector expenditure on agricultural research has fallen worldwide and there has been rapid concentration in the private sector,

where a few multinationals dominate. These companies are accumulating intellectual property to an extent that the public and international institutions are disadvantaged. This represents a threat to the global commons in agricultural technology on which the green revolution has depended. Estimates of the increased R&D expenditures needed to feed 9 billion people by 2050 and how these should be targeted, especially by the Consultative Group on International Agricultural Research (CGIAR), show that the amounts are feasible and that targeting sub-Saharan Africa (SSA) and South Asia can best increase output growth and reduce poverty (Piesse and Thirtle, 2010). A report by Beintema *et al.*, (2012) has estimated that, in 2008, global public spending on agricultural R&D totaled \$31.7 billion in inflation-adjusted, purchasing power parity (PPP) dollars. The expenditures were split roughly evenly between high income countries and low- and middle-income countries, hereafter referred to as “developed” and “developing” countries, respectively. Public agricultural R&D spending in China, India and Brazil—the three top-ranked countries in terms of public agricultural R&D spending in the developing world—accounted for one-quarter of global spending and half of combined spending in developing countries.

Following a decade of slowing growth in the 1990s, global agricultural R&D spending increased by about 22 per cent during the 2000–2009 period, from \$26.1 to \$33.5 billion in 2005 PPP prices. This corresponds with the average growth of 2.4 per cent per year, about the same as the 1980s rate. Accelerated R&D spending by China and India accounted for close to half of the global increase of \$5.6 billion during 2000–2008. Focusing only on agriculture-related research—excluding food processing and product development—global R&D spending by the public and private sectors combined totalled \$40.1 billion (PPP) in 2008, of which 79 per cent was performed by the public sector and 21 per cent by the private sector. Most of the private-sector R&D was carried out by companies based in OECD countries, but many of these companies maintain experiment stations in developing countries in order to transfer new proprietary technologies to these markets (Fuglie *et al.*, 2011). Information on private sector involvement in developing countries remains limited, but evidence suggests significant growth in large middle-income countries. Research investments is only one metric by which the growth of agricultural R and D can be measured. Quality of research programmes, human resource capability and quality, intensity of infrastructure availability for advanced research, strength of academic programmes, collaborative research capacities, ethical and value systems governing agricultural research are equally important for converting the research investments into knowledge and technologies. Therefore, inter-country comparisons of research investments are fraught with serious problems because of the absence of parity in non-monetary dimensions mentioned above.

Indian Scenario

A well-known rule of thumb for optimal research expenditure is to allocate at least one per cent of agricultural gross domestic product (GDP) to agricultural research. However, Roseboom (2003) suggests an investment target of 2.5–3.0 per cent of agricultural GDP with the assumption that developing countries face the same innovation opportunities as developed countries. Between 1996 and 2009, India's total public sector R and D expenditure has increased by about 145 per cent from 929 to 2276 million 2005 PPP dollars. India's share in global agricultural R and D expenditure has increased from 2 per cent in 1960 to 6 per cent in 2009 and its ranking improved from 13th position in 1960 to 4th in 2009. However, India has invested a lower percentage of its agricultural output in research than either Brazil or China, both in absolute terms and as a share of its agricultural GDP. In spite of the significant increase in public investment in agricultural R and D in India, the investment intensity still remained much lower at 0.4 per cent of agricultural GDP during the year 2009. The growth in agricultural productivity in India in terms of total factor productivity (TFP) has been declining in recent years on account of slow-down in agricultural research investment, infrastructural development, institutional changes, slow spread of even the available promising technologies and not much improvement in technologies (Kumar, 2001). The policy and institutional reforms affecting agriculture and agricultural research have also been less pronounced in India than in the other two countries (Fuglie and Schimmelpfennig, 2010). In India, agricultural R&D spending by the private sector has increased five-fold since the mid-1990s (Pray and Nagarajan, 2012), such that by 2008–2009 it accounted for 19 per cent of the country's total (public and private) agricultural R&D spending (Pal *et al.*, 2012). This is almost close to the share of private sector investments in agricultural research at the global level. Between 2000 and 2008 India, China and the USA have been the main drivers of the growth in global public R and D expenditure in agricultural research. However, India still accounts for only 7 per cent of total global R and D expenditure even though India account for 17 per cent of the world's population. India's 12th five-year plan for the period 2012–17 has set an agricultural R&D intensity target of one per cent of agricultural GDP been approved, in principle, by the national government but some argue that this was still insufficient, leading to a call for a 2 per cent target, which has been approved, in principle, by the national government.

Thanks to the IPR regime and more focused research on regional and local agricultural issues, the agricultural research outputs from many developed countries are becoming increasingly proprietary in nature with local research emphasis. Further, increasing proportion of investments from both private and public sector are made on off-farm science including health, nutrition, food safety, biofuels and environment. All these recent developments would mean diminishing scope for spillover benefits from research in developed countries to developing countries.

Therefore, significant public research expenditures are needed in future in order to accelerate the growth in agricultural productivity, while at the same time providing research capacity to help guide sound public- and private-sector decisions on a multitude of evolving food system issues. These research investments are also important tools for agriculture to maintain its role in contributing to the strength of the Indian economy. Returns to research investments vary widely depending on research priority and research focus, the quality and management of investments, research and extension capacity available, etc. For example, in the early periods of green revolution, the potential yield differential and genetic traits among diverse genetic resources of a species was wide and there was huge genetic potential to be productively exploited for yield improvement. This, together with high quality manpower and investments made productive research infrastructure, contributed for higher marginal impact of research investments. There is a wide diversity in nature of crops, socio-economic and agro-ecological conditions prevailing in the country together with wide variation in institutional and organisational arrangements for managing research investments across ICAR institutes and SAUs, and within SAUs across states. This calls for careful prioritisation of research investments so as to ensure maximum rates of returns to agricultural research and to avoid duplication of research programmes. Research prioritisation remains to be a distant dream, in spite of sporadic academic exercises. Whenever funds are limited systematic research prioritisation and priority-based research have to be made mandatory. Research prioritisation may be done using simple methods like participatory research involving stakeholders from the beginning of the research. Simple and low-cost prioritisation tools such as yield gap analysis, opinion survey among farmers and the extension officials, and domain-experts' opinion on high impact technological solutions might also be useful.

Policies and investments, 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). The less-favoured areas in India—characterised by resource-poor, rainfed, small and marginal farmers, poor infrastructure and supporting services—cover 70 per cent of the cropped area, contributing nearly 40 per cent 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 lower productivity and persistence of poverty. 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' needs precisely and also due to the lower research intensity in the rainfed areas. 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 research and extension agents such as farmers' organisations, producers' co-operatives, input firms, media and voluntary organisations 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 by various agencies. Similar issues haunt the extension system in dryland and rainfed areas, which is mainly due to the lack of high-impact technologies for rainfed areas. A review of evaluation studies on the Training and Visit system revealed its impressive gains (in terms of productivity) in irrigated areas and its failure in making impact in the larger part of 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. NARS commodity portfolio is highly diversified. Within ICAR system, more than two-third of all commodity-oriented research is devoted to food (food crops, livestock, and fisheries) research (68 per cent of total commodity-oriented research). Pulses still appear to be under-emphasised in the ICAR agenda (12 per cent share). Rice accounts for more than half of all cereal based research, wheat and maize claim another 34 per cent (Jha, 2004). In addition to the balance in research focus among and across various crops and other sectors such as livestock, forestry and fishery, there must be a balance between basic and applied research programmes. Therefore, the future investments in agricultural research and extension should be more broad-based as well as intensified on the basis of well-prioritised, demand-driven approach towards generation and supply of agricultural knowledge and technologies.

Another critical issue in research investment in agriculture is the inadequate allocation of financial resources for building laboratory and experimental facilities and human resource capacity building. While it is absolutely important to address the issue of research investments focusing on both the quantity and composition of research spending, more often than not we find that there is a mismatch between salaries and non-productive expenditures on the one hand and infrastructure and skill development investments on the other. Salaries and other employee compensation takes a major share in the agricultural research investments by the State Governments. Turns out that there is a compelling need to find and implement an optimal ratio between salaries and non-salary research expenditures, especially towards experiments and research infrastructure. Inadequate understanding of the role of agriculture in poverty alleviation, weak and inconsistent political leadership, poor bargaining power of farm lobby and agricultural research system, and long gestation period of agricultural R and D as compared with other investment options together with shortsighted outlook and policies of governments are the major reasons for the under-investment in agricultural R and D in India.

Research Policy and Institutional Issues

Farmers, in general, and the farmers in developing countries such as India, have low political voice, coupled with policy makers' lack of knowledge of potential for pro-poor growth contribute for low priority attached to agricultural research and development. Prior negative experiences with agricultural projects together with decentralised impacts that are often spatially thinly spread contribute significantly to the political and institutional apathy towards agriculture in general and agricultural research in particular. An important constraint facing agricultural research is the lack of long-term research policy for agriculture. Clearly-defined research policy with specific goals, programmes and strategies along with common codes of administration and management of research is essential. Massive revamping of the process of research including research prioritization, research project formulation with stakeholder involvement, human resource planning and management, and internal and external supervision, monitoring and evaluation of research programmes and projects are the key components of research policy. These components are the necessary conditions, but not sufficient conditions, to accelerate the progress of agricultural development led by innovations in frontier areas. Uniform and scrupulous implementation of such a research policy is a huge challenge in a socially, politically and economically diverse country like India. The emerging trends in national agricultural research systems of different countries facing similar issues and constraints as well as the international agricultural research systems should be considered while formulating such a policy. The global economic environment, changing consumption patterns such as shift away from cereal crops, trade-related issues, etc should also be given serious attention in formulating agricultural research policy. The broader context and contours of agricultural research and development needs particular attention in framing research policy.

The appointment of top-level research managers in the national agricultural research system lacks transparency without any well-codified procedural guidelines. Due to the highly politicised and opportunistic appointments for top-level management, the agricultural research system has become insensitive and indifferent towards the ongoing crisis in agriculture, degradation of human resources and research programmes. Further, the institutional and organisational forms and the incentive structures remain unchanged keeping with the changing realities. Colonial and conservative management style does not accommodate modern ways of thinking and critical analysis of issues. As aptly emphasised by Mruthyunjaya (2012), investments in organisational and management reforms to overcome financial and operational problems has to be treated as important as investment in research. Institutional arrangements for quality control in research programmes, research outcomes and manpower development are rather weak. With a huge number of institutes and universities and the research centres/stations within the SAUs' ambit, it is increasingly becoming difficult to monitor the research activities on a continuous

basis. With the multiple agricultural universities or more speciality universities such as the ones for animal sciences, horticulture and fisheries, the scale and scope economies in agricultural research is lost as also the farming systems approach. Multi-disciplinary and collaborative research gets weakened as we create more and more speciality universities along disciplinary lines. All sciences dealing with farming such as agriculture, horticulture and animal sciences including fisheries should be under one single university so as to generate and provide farmers with holistic technological solutions, know-hows and information. If at all it becomes too unwieldy for a single university to efficiently manage the research and educational programmes due to their sheer size, it is much desirable and more effective to create another agricultural university by carving out the existing one(s), rather than creating universities for narrowly defined disciplines. In fact, a report on Agricultural Science and Technology Indicators sponsored by IFPRI (Stads and Rahija, 2012) makes a specific argument that the research capacity in India's SAUs is weakened along with fragmentation (of universities) along disciplinary lines.

Inadequate understanding among agricultural scientists of the farm-level problems within the broad socio-economic context contributes for inadequacy of demand-driven and problem-solving research. Agricultural research system is fairly well-insulated from taking inputs from disciplines such as social sciences, natural resource and environmental sciences as well as from other non-research actors like civil society movements and farmers' organisations. Though our biological scientists have contributed enormously to the growth in agricultural productivity, we still have a large number of them, without a broader understanding of the special problems facing Indian agriculture, with a very limited resource base and other constraints such as credit and labour. It is often the case that some or all of these important constraints have not been explicitly taken into consideration in their technology development programmes. Developing cost-effective, labour-saving, and less-water-intensive crop varieties and/or technologies is not an easy task, because of the extremely limited possibilities as we impose more and more constraints. Hence, addressing the production constraints of specific farming situations prevailing in India requires a holistic approach covering technological, institutional and infrastructural issues and constraints. The lessons learnt from several ongoing and past programmes such as All India Coordinated Research Projects, National Agricultural Technology Projects, National Agricultural Innovation Projects, National Agricultural Development Project, and other completed and ongoing projects should be systematically summed up at regular intervals. The process of summing up the experiences of implications of the research projects for the future research strategy and programmes should be institutionalised with clear guidelines.

Another important lacuna in most of the current research programmes is the lack of specific plans and strategies for commercialisation of technologies generated. Commercialisation should be programmed into the project right at the beginning of the research project. Tie-up with commercialisation partner preferably from a private

agro-industry shall form part of applied agricultural research projects. Though we have mechanisms such as extension council and research councils to effectively transmit the needs of the farmers/stakeholders to the researchers, these arrangements have become rituals and failed to serve their purpose. Therefore, an important step in ensuring commercialisation is the stakeholder involvement in the very beginning of the project formulation. Stakeholders must include the extension workers, seed or machinery producers, food processing companies, large-scale traders or exporters, and the farmers and consumers too. It is often the case that stakeholder participation is almost nil or very minimal in the early stage of project formulation. Further, publication and product development and commercialisation must be made compulsory components of all applied agricultural research programmes.

The systems of human resource and financial management within the SAU system is completely outmoded and unscientific with scant regard to flexibility and programme- or project-specific requirements. The manpower deployment policies, financial management and grant approvals for new projects and new initiatives by scientists are highly bureaucratic and/or centralised, discouraging rather than encouraging, and disabling rather than enabling. In most agricultural universities, the establishment rules of the respective state governments are scrupulously and mechanically imposed on the scientists and scientific programmes without any regard to the differences in pursuits and objectives of the government machinery and the intellectual pursuit of science and education. There is almost complete top-down approach to research management, manpower planning and deployment, and management of research grants with very little flexibility or freedom to the researchers concerned. After years and decades of debating about institutional autonomy, and more powers and functional autonomy to the scientists in the financial and operational management of their research projects, we are moving more and more towards autocratic, bureaucratic and top-down modes of administration and management. This is one of the topmost issues that need to be addressed in order to revamp the research system. Therefore, what we experience in agricultural research, extension and education is a serious crisis, given the current political and socio-economic milieu. This trend, in all likelihood, is likely to worsen in the foreseeable future due to the continuance of past trends that have created the present state of affairs as well as opening up of agricultural education to private investments, without adequate mechanisms for quality control. The multiple problems facing Indian agricultural research system are complex covering a wide array of internal and external causes and effects thus entering into a vicious cycle.

Issues in Organisation and Management of Agricultural Research

India has one of the largest and well-coordinated public agricultural research systems in the world. Its primary agencies are organised under the Indian Council of Agricultural Research (ICAR) and state agricultural universities (SAUs). Strong

government commitment has resulted in a near doubling of public investment in agricultural research and development (R&D) since the mid-1990s. Funding is expected to increase further in the coming years. Public agricultural R&D is almost completely funded by the federal and state governments. The number of researchers declined by 17 per cent during 2000 to 2009, which was most pronounced at the SAUs. The number of full-time equivalent agricultural researchers per million economically active agricultural population in India has declined from 56.6 during 1996-2000 to 43.6 during 2006-09. This is much lower as compared to the neighbouring countries such as Pakistan where it was 144.4 and Sri Lanka which had 156.5 (Stads and Rahija, 2012). The reduction in research manpower has happened in spite of the steep increase in the number of agricultural research institutes, especially the agricultural universities which increased from 34 in 2004 to 56 in 2012 (Table 1). This only points to the fact that more and more institutes/universities are created merely by redeploying the existing research manpower.

TABLE 1. GROWTH OF INDIA'S NATIONAL AGRICULTURAL RESEARCH SYSTEM

Institutions (1)	1960-70 (2)	1970-80 (3)	1980-90 (4)	1990-00 (5)	2004 (6)	2012 (7)
Deemed Universities	-	-	-	3	4	4
State Agricultural Universities	13	24	26	29	34	56
ICAR Institutes		26	-	41	45	47
National Research Centres	-	-	-	20	31	17
National Bureau	-	2	2	4	5	6
Krishi Vigyan Kendra	-	33	108	259	329	631
Project Directorates	-	-	-	-	12	25
All India Coordinated Research Projects					91	88*

* Includes 17 Network Projects and 10 other projects.

One of the important issues with ICAR research system is probably the limited understanding of the local needs and requirements of technologies by the scientists, as the scientists in these institutes come from different corners of the country. Though the SAU research system has fairly strong relationship with state-specific extension agencies, such a mechanism is either weak or non-existent in ICAR research system. A healthy competition between SAU research system and ICAR research system should coexist with strong coordination and collaboration between these two systems. The strengths of the two systems should be shared liberally through a formal, well codified memorandum of understanding. The State Agricultural University research system has a number of advantages over ICAR system in the sense that it is primarily dependent on own-state scientists, has strong linkages with state-level extension agency, and through its educational programmes, SAU system produces technical manpower for agricultural research. This offers the SAU scientists multiple pathways of learning, and practicing their technical knowledge and obtain faster and effective

feedback on their teaching, research and extension activities. It is of course a moot point whether these advantages are effectively harnessed by the SAU system and its scientists.

In spite of the several advantages of the SAU system, there are a number of challenges and problems plaguing the SAU system in many states of the country. Instead of having diversified disciplines under one university, there is a mushrooming of State Agricultural Universities with more and more universities for very narrowly defined fields such as forestry, fishery, horticulture, veterinary sciences and so on. Such a growth in universities with highly focused specialisation undermines the unified and interdisciplinary treatment of agriculture and allied subjects, given the multi-functional nature of agriculture and the way it has been practiced in India. Too much of controlled condition experiments must give way to more of on-farm trials with adequate involvement of farmers, possibly final consumers, processors or people from value adding industries, and traders. Large number of research stations with thinly spread manpower and infrastructure facilities effectively undermines the threshold research inputs required to make significant scientific progress and innovation. Quality of management and research administration also becomes problematic when the size and number of research stations increase beyond the threshold level. The principal-agent problem gets worsened and deepened when the number of management units and number of management tiers increase. These are not just potential threats but are already devouring our research capacity, together with the discredited manpower deployment and human resource management policies of the most state agricultural universities and national research institutes.

In recent times, when the quality of agricultural research manpower is subjected to significant attrition, and a large proportion of research investments go for salaries and other unproductive costs, it might be unrealistic to expect an all-round increase in technological outputs and productivity growth in agriculture. The stagnation in agricultural productivity and farm profitability is often attributed to degrading resource quality and technology fatigue. A large part of the so-called technology fatigue could be attributed to what one is compelled to call the “human resource and institutional fatigue” in research and extension caused by erosion of research ethics and social values caused by a host of other institutional, policy, and human capital issues. Human resource fatigue is caused by aging of manpower due to very low new intakes, lopsided and imbalanced cadre strength at various research positions, perverse incentive system in many SAUs and institutes, lack of quality manpower at entry level, and various “other” problems in recruitment of quality scientists. Institutional fatigue is caused by short-term interests of the decision makers and research managers, principal-agent problems in execution, monitoring and evaluation of research programmes, increasing diversion of human resources for non-research purposes, and indifference towards agricultural research by the Governments at various levels.

Specialised Disciplines or Specialised Scientists?

Specialisation is a key requirement in increasing productivity—be it physical work or scientific endeavour involving brain work. Perhaps the first lesson of agricultural research in India is to disregard specialisation. Within the agricultural university system, it has now become trendy to create very narrowly-defined, often fictitious fields of research centres, divisions or departments according to the whims and fancies of the powers that be. In spite of such a narrow specialisation at departmental level that is often dubious in nature, there is hardly any “real” specialisation among the scientists. Instead of creating such quirkily specialised departments or disciplines, the agricultural research system should promote specialisation among scientists, which is long overdue. Transfer of scientists against his/her will, and out of his specialised area of work has become an annual ritual and it has come to dominate our agricultural research system almost throughout India. This wrecks havoc on the capacity building, the real specialisation, and human resource development in agricultural research. The existing system of transfer policy and manpower deployment across space and specialisation should be replaced by a farsighted and well-planned system of manpower distribution.

Human resource management and the needs of the state’s agricultural sector and regional agricultural research priorities should solely dictate the manpower deployment policies within the research organisations, rather than the individual prejudices in the name of ‘administrative convenience’. The so-called ‘administrative convenience’ in manpower deployment should be replaced by an objectively and systematically codified archetype of manpower planning based on research needs. To overcome the problems associated with optimal deployment allowing for specialisation, it is necessary to introduce a new system of scientists recruitment for specific vacancies in research station/research centre, rather than making recruitments at University level and then deploying them to various centres. Another solution is to close down uneconomic research stations/centres/institutes with poor track record. It is viable and optimal to have one research station for each agro-climatic zone. If at all manpower redeployment through transfers is necessary, it should preserve specialisation intact and ensure that this does not in any way affect the ongoing research programmes. Policy makers should be convinced to view agricultural research not as an employment generation opportunity but as an output-oriented scientific venture, so that starting newer and more research stations/centres will cease and the unproductive ones will be closed.

Collaborative and Multi-Disciplinary Research

There is duplication and lack of collaboration and coordination among various universities, ICAR research institutes, within SAUs, and between ICAR institutes/SAUs vis-à-vis a few conventional universities where either some basic

and/or applied research related to agricultural sciences are undertaken. Duplication and the absence of coordination or collaboration are the two sides of the same coin. Though some amount of duplication is unavoidable, this problem may be addressed by an institutional arrangement to document the past and ongoing research through modern information management system, and an organisation for implementing it. Agricultural research is plagued by too much of shallow, short-term, person-oriented and publication-oriented research. All these problems are interlinked with each other. In a highly person-oriented research endeavour, research projects are conceived based on established links, donor interests, and funds availability rather than being demand-driven, inter-disciplinary, holistic, collaborative, and farsighted. Further, person-oriented rather than team- and theme-oriented research, leads to yawning gap and discontinuity in the research programme once the particular researcher leaves or retires from the institute.

Through concerted efforts in fostering inter-state, inter-regional and inter-institute collaborations, it should be demonstrated that state and regional boundaries are artificial and focusing on issues and best available knowledge has strong merits. There are several key aspects to the success of collaborative research projects: the research issue must be the driver; investment in core competency and infrastructure; identification and nurturing of expertise, regardless of location; ensuring that the programme is compelling to the experts, in both funding and time; ensuring accountability, without interference in research project and project collaborators. Collaborations with commodity groups, corporate sector and foundations are necessary to establish competitive, multi-disciplinary centres of agricultural research excellence. While competition between research institutes is a healthy trend, complementarities and collaborative works should take precedence. Collaborative research between leading basic science research institutes—both public and private—and the applied research programmes at SAUs/ICAR research system is necessary. Inter-institutional and international collaborations should become a long-term, truly inter-institutional venture and product-oriented one led by commercialisation, rather than short-term, scientist-to-scientist collaboration aimed at publication. Collaboration of SAUs and ICAR institutes with other institutes such as CSIR institutes, Indian Institute of Science, conventional universities, etc., need to be strengthened.

Biotechnology – The Deadlock and the Way Out

It has become a cliché to say that biotechnology offers huge potential to overcome the fatigue in agricultural productivity growth. Indeed, genetically engineered crops are now a reality for many farmers in the US, Canada, China, India and Argentina and many other countries are joining the group. For the developing world, biotechnology promises crop varieties that are genetically better suited for prevailing production conditions and stresses. Two major observations apply to

biotechnology and the developing world: one, it seems unlikely that biotechnology will address the needs of the poor in the poorest regions without concerted public efforts; and two, it holds little promise of ever addressing some of the important needs of the farmers. Multinational seed companies, the major players in plant biotechnology, will not turn this potential into reality in the poorest and most in-need developing countries, certainly not in the short run. There are simply too many more profitable opportunities for big companies to pay much attention to the poorest countries. Therefore, some of the most important conditions for agricultural growth in developing countries cannot be addressed solely by biotechnology. Agricultural production requires good soil fertility, appropriate policies, markets for inputs and products, credit, and educated farmers. There is widespread hope that biotechnology can make crops more drought-tolerant, and in the case of maize there appears to be progress. In rice, while the quest for some degree of drought tolerance has been considered intractable, many rice scientists, now believe that genetic improvement for this trait is possible given the recent advances in rice molecular biology and genetics. In the climate change scenario, genetically modified crop varieties with tolerance to higher temperatures and extreme weather events will be an important contributor to sustain agricultural productivity.

Though the private sector, which is making huge investments in biotechnology, claims substantial social benefits, the opponents argue that biotechnology research by private firms impose huge social and environmental costs. The area under genetically modified crops has increased by 100 fold from 1.7 million ha in 1996 to 170 million ha in 2012 (James, 2012). However, strategic and profit-oriented research interests of private biotech industry is often cited by the critics as an important rationale behind their opposition to biotechnology, even though similar kinds of opposition was not voiced against biomedical research by pharmaceutical giants. The biotechnology research and field trials have been subjected to more controversies than medical research probably due to the lower priority and urgency attached to solving agricultural problems than human health issues. The recent violent protests against genetically modified, golden rice trials in The Philippines, in spite of the fact that this particular technological venture is a public undertaking, is a major blow to future field trials in Asia, and probably in several other parts of the world. The international and national agricultural research system should undertake a thorough and critical appraisal of the pros and cons of biotechnology and settle the controversy sooner so that at least the field trials could be carried on in pursuit of scientific verification of the claims. Appropriate biosafety protocols should be put in place so that the benefits of science and technology will reach the farmers sooner. Further, inordinate and unjustified delay in granting approvals for GM food crops might discourage the private sector in making future investments in food crops. Governments of both developed and developing world should come forward to make strong assurances to the skeptics and environmentalists and make firm commitments to protect the biodiversity from being threatened by biotech revolution. This will, to a great extent,

dispel the threats perceived by skeptics and opponents of biotechnology.

Managing the “Ultimate Resource” in Agricultural Research

Simon (1981) coined the term “ultimate resource”, in his book of the same title, to describe the human capital—viz., human knowledge and skill that will substitute almost perfectly and infinitely to make up for scarcity in natural resources such as gas, minerals, trees and fishes. In agriculture, the role of this “ultimate resource” is immense in the emerging era of fast-declining land, and water resources, as well as human (physical) labour. Human skills have to substitute for increasing scarcity of material resources that will enable more and more production with less and less land and water. Human resource capacity refers to both the quantity and quality of scientific and technical personnel employed in national agricultural research system. It is the talent pool and skill-set embodied in the entire research manpower, and hence it is the onerous and compelling duty of the state to identify, develop, and harness this precious resource. It is the elementary microeconomic fact that markets divert resources to those uses where their marginal productivity is the highest. However, in a labour market such as scientists, it is quite often the fact that we end up getting highly skewed distribution of manpower across research and other professions as well as across public institutions and private research enterprises. In a socio-economic environment where everything is looked upon as an employment opportunity which is an end in itself, it is a daunting task to harness the quality manpower for agricultural research. However, evolving environment-friendly and productivity-enhancing technologies will be high-tech and skill-intensive in future, and hence would require high quality manpower. Without an assiduously devised manpower planning, it is impossible to upgrade the quality of manpower required to meet the current and emerging challenges in agricultural education, research and extension.

The probability of success and cost of innovation are a function of the state of basic science, availability, quality and costs of scientific inputs such as scientists and laboratories, and the overall institutional environment and socio-economic context within which the research is conducted. Advances in basic science can lead to new possible products from applied research. Breakthroughs in basic science will be a critical input for applied research to overcome yield stagnation and building the desired crop characteristics to meet the growing domestic and export demand and ensure nutritional security. However, research on basic sciences within the ICAR/SAU system is very meagre and requires huge investments, human resources, and infrastructure facilities. This shortcoming could be offset to a significant extent through partnerships and collaborations with advanced basic science research institutes in both public and private sector such as CSIR, CCMB, IISc, IITs, and so on.

The human resource availability for agricultural research in India were falling as a result of reduced recruitment of research staff at state agricultural universities and a

shift away from research in favour of teaching (Pal *et al.*, 2012). This falling trend coupled with their increasing workload and engagements with non-research activities such as extension, education and administration has considerably reduced the manpower for agricultural research. Further, the scientists in most agricultural universities and research institutes are bound to their laboratory and/or experimental field, and completely disengaged from the farming community and their needs and aspirations. In recent times, more and more scientists in SAUs and probably those in other institutes are after power and hence prefer to be administrators rather than scientists. An important reason for this situation is the degradation in overall research environment, unscientific and research administration hostile to the pursuit of science, and socio-economic and political disarray, and it has very little to do with the individual scientist or the current leadership at the institute or the university. When the entire system is on a downward spiral, none of its components can be blamed, nor one from inside the system can stop it; it requires an external force—a thoroughly determined and dedicated force—to understand the problem in a proper perspective and take credible efforts to stem the rot.

Despite some positive developments in agricultural R&D, the SAUs and other agricultural research institutes continue to face important capacity challenges. In some states, long-term recruitment restrictions in public sector have skewed the average age of scientists to the higher end of the spectrum. Even in institutions where some amount of new scientific manpower recruitment takes place, the scientific caliber of the new recruits is dubious in nature thus causing a net attrition in overall research capability. This problem is particularly severe in countries like India, especially in its State Agricultural Universities. Government institutions in countries that have been able to lift long-term recruitment bans have often had to contend with influxes of young, inexperienced scientists (qualified with only bachelor's or equivalent degrees) in need of appropriate training but lacking mid-level mentors to guide them. Attracting and retaining qualified research staff is a major challenge across developing countries. Low salaries and conditions of service in public agricultural R&D institutes have been the main cause of "brain drain" to the private sector, international institutes, or abroad. Moreover, in-country postgraduate and post-doctoral training opportunities are often limited. This is especially true in developing countries like India which are challenged by low human resource capacity and funding volatility, and lack of ability to take advantage of economies of scale and scope. The lack of a critical mass of well-qualified researchers highlights the need for regional initiatives that focus on better use of limited resources and the reduction of wasteful duplication.

The key issues in agricultural research manpower development may be summarised as below:

- (i) Lack of planned manpower development: As manpower development forms the core input for any research system its importance in agricultural research need

not be overemphasised. Planned manpower development encompasses an array of critical requirements such as complete assessment of manpower required in each discipline, timely recruitment, quality control, in-service capacity building, identifying and nurturing of talents, and suitable facilities that will match the quantity and quality of manpower.

- (ii) In-breeding: In-breeding is a major problem plaguing agricultural research and education in our country and it is both a cause and consequence of immobility of scientists across geographic regions and across institutions.
- (iii) Perverse incentive structures: Incentive system including pay and allowances and promotion norms should be different for institutions/universities with and without research commitments. The pay scales for agricultural scientists are devised mainly based on the working culture of government departments and/or conventional universities where research is either non-existent or a second priority. Time-bound promotion through career advancement has become a standard practice of career elevation for almost all scientists and cadres. This turns out to be a real disincentive for scientists with exemplary track record of research and publication. Therefore, incentive structure and career development norms should be devised exclusively recognising the research outputs of scientists with transparent set of guidelines. Both monetary incentives and motivational factors should play critical roles in enhancing and sustaining human resource capabilities.
- (iv) Existing research manpower in most agricultural research institutes and State Agricultural Universities are overloaded with too much of administrative, teaching and non-technical works. An adequate number of supporting administrative staff should be provided based on a uniform norms and guidelines.
- (v) There is a sharp increase in the number of private colleges offering agricultural degree programmes in recent times. Given the inadequate institutional mechanisms and organisational capability to monitor the quality, the proliferation of agricultural colleges will lead to lowering of quality. Too much of graduates passing out will lead to larger unemployment for them resulting in well-qualified students getting crowded out towards engineering and other subjects. Hence, over the years there will be a secular decline in the quality of students opting for agricultural degree programmes. Large amount of low quality manpower coupled with reduced research outputs will lead to increased cost per unit of research output and discourage future research investments.

- (vi) Though huge amount of public resources are used for post-graduate research, it is disheartening to note that the outputs do not commensurate with the investments, and their outcomes do not go beyond laboratories and academic journals. Post-graduate research in agricultural sciences needs to be critically reviewed at University/institute level as well as at the national level. The research topics for post-graduate and doctoral studies should be well-knit with the overall mandate of the Departments concerned, as well as with the ongoing research projects of the Department.
- (vii) Research ethics and value systems in agricultural research and extension are put to tremendous challenge in recent times. Ethics and value systems for any particular profession or any particular aspect of social life cannot be sustained without a broader environment that is equally ethical and value based. Agricultural research system, or any profession for that matter, cannot be viewed in isolation from the overall economic system and societal value systems. This is one of the most important—in fact the single most important—challenge that we face today in almost all the disciplines of science. Myopic planning and the lack of coherent and democratic decision-making and management are informed, rationalised and sustained by short-term gains and populist agenda. Interest groups and political lobbies are occupying every aspect of social and economic life thus creating a huge crisis in most spheres of life. It is, therefore, next to impossible to talk about reinvigorating agricultural research or agrarian crisis without considering the large malaise afflicting our society and economy.
- (viii) From ‘publish-or-perish’ to ‘publish-and-perish’ mode: When it is justified to question the purposeless proliferation of State Agricultural Universities (SAUs) including narrow disciplinary universities, research centres and departments, it is equally justified to debate the unfettered growth in the number of academic journals and conferences. As research output is increasing in quantity, though not necessarily in quality, there is a need for increase in number of journals and conferences, since the question of quality itself can be put to test mostly by publications or presentations in the conferences. However, it could be noticed that proliferation of journals and conferences is often profit-oriented, sub-standard and corporatised, and feeds on the needs of the publication-oriented research and publication-oriented career growth of scientists. Impact factors and publisher fame are often the metrics used to judge the merits of the journals. Such a complicated processes of testing the contribution of scientists takes a heavy toll on demand-driven research rather than publication-based research. It is, therefore, necessary to evolve an institutional mechanism to reorient career development norms based on the utility of findings and/ or innovations and their replicability and upscaling, and contributions to problem-

solving, in addition to the current norms of publications and non-academic contributions. This will also mitigate the problem of unethical publications based on dubious and/or publication-oriented research.

Agricultural Extension System

The balance between agricultural R&D and extension has long been an issue, and as suggested by many critics, many of the extension workers had nothing to extend owing to weaker research and development, and the poor research outputs. Also, extension has tended to be the weaker link at the bottom of the funding chain (Thirtle and van Zyl, 1994). This has resulted in the entire budgets being spent on recurrent items like salaries, while there were no funds for farm visits and other important extension activities. Despite this disheartening trend, Evenson's (2001) survey of the impact of extension services showed a median IRR of 80 per cent, but with a large variance. As studies have become more sophisticated, especially by allowing for international spillovers of technology (Schimmelpennig and Thirtle, 1999), rates of return have fallen to more reasonable levels of around 30 per cent. Evenson and Pingali (2007) took a different approach, showing that there was no correlation with extension officers and the adoption of green revolution modern varieties. Many countries with an abundance of extension personnel did not have a green revolution. This suggests that the causes of failure and success in extension need to be examined critically and systematically.

The main constraints in the present model of agricultural extension system in countries like India are the bureaucratic control and bureaucratic mode of agricultural extension system, and the consequent top-down approach towards the priorities and information contents of the extension system. Another major challenge in building an effective extension system is the lack of continuity due to frequent changes in political establishment, agricultural secretaries, and other top-level officials managing the state-level extension system, etc. There is limited space for the views of farmers, grassroot level organisations and field-level functionaries in our model of agricultural extension management including conceptualisation, formulation and implementation of extension programmes and projects. The research and extension councils should include farmers and other stakeholders including the field functionaries of extension system from different regions and socio-economic backgrounds to adequately represent their needs and constraints.

Feder *et al.* (2001) suggest there are some generic and universal difficulties in the operation of public extension systems and in the bureaucratic-political environment within which they are budgeted and managed. They find eight factors that can cause deficient performance: the scale and complexity of extension operations; the dependence of success on the broader policy environment; the problems that stem from the less than ideal interaction of extension with the knowledge generation system; the difficulties inherent in tracing extension impact; the profound problems

of accountability; the weak policy commitment and support for public extension; frequent encumbrance with public duties in addition to those related to knowledge transfer; and the severe difficulties of fiscal unsustainability faced in many countries.

Many of our technologies as well as extension methods are subsidy-focused or subsidy-driven, rather than need-based and demand-driven. Efforts should be made to make the technology adoption process self-sustaining rather than being sustained by subsidies and other supports. Subsidies should be replaced by a system of more carefully crafted credit and insurance delivery mechanisms and institutions. The demand for extension services is itself determined outside the extension system, mainly by the quality, suitability and the perceived impact of the technology, the resource base of the farmers, other constraints such as credit, labour, water, etc. Weather forecasts, production information, and marketing information are decoupled from each other. Integrated or single-window provision of knowledge and information on credit and insurance, market and price information including input price trends, and weather information needs to be strengthened.

The current definition of extension is narrow which is synonymous with mere transfer of technology, mostly focusing on crop production issues. Overall farm management including the management of on-farm and off-farm resources such as groundwater, canal water and common pool irrigation resources such as tanks are all absent from the purview of our extension system. Even farming system approach is largely missing from our extension activities. Farmers' experience with the maintenance of optimal mix of various enterprises needs to be given due care and attention in designing the extension activities for different farming systems within each agro-ecosystem. The investment potential, credit availability and credit and labour constraints need to be taken into consideration while making recommendations to the farmers. The gap between the potential and the optimal yield (or performance) of crops and technologies need to be carefully studied under different agro-ecosystems with a due care to differences across villages or even farms within a village in terms of productive capacity of the resources and other constraints. This is a very critical input for extension functionaries, because quite often the objective of extension activity is to bridge the yield gap or the difference between optimal performance of a technology and its current performance at the farm level. Unless the gap (yield gap or performance gap) is perfectly established along with the possible causes, it is very difficult to bridge the gap(s).

Success and failure stories should be summed up periodically and systematically so as to inform the process of future course of action. The feedback mechanism between extension system and research system should be made more institutionalised and governed by a specific set of clearly-defined rules and goals rather than being informal and/or ambiguous. In spite of the sporadic attempts and assurances, establishment of model farms remain elusive. Model farms should be established representing all types of farming systems in each agro-ecosystem or agro-climatic region. Their economic and environmental sustainability should be demonstrated

through a system of locally devised propaganda mechanism that suits the local cultures, customs and social institutions. Linking agricultural extension system with other on-going agricultural and/or rural development programmes such as watershed and wasteland development, national rural employment guarantee programme, etc., should be pursued seriously. Providing farmers with knowledge on the long-term viability and sustainability of the existing and recommended farming system or variety or production technologies is essential. The farmers should be adequately educated about the changing trends in consumer preferences, emerging priorities of middle class in agri-food consumption, trends in global agri-commodities markets, etc. so as to make them capable of making informed decisions about their long-term priorities.

Indian agriculture is dominated by small and marginal farms. Extension efforts among such a widely-dispersed, numerically and geographically inaccessible masses is surely a daunting task given the poorly or moderately developed rural infrastructure in our country. Therefore, suitable mechanisms should be developed to provide appropriate mobility packages to the extension functionaries so as to enable them undertake arduous field visits with minimum stress. These efforts should be complemented by investments in modern techniques such as ICT-enabled extension services including e-extension. Farmer-to-farmer spread and sharing of knowledge and information should be encouraged through networks such as producer groups, commodity groups, and self-help group modes. Some of the important measures which can strengthen the public extension services include the following:

- Correctly identifying the requirements of each beneficiary group and customising extension services to suit the needs of each beneficiary group, so that they become total solution providers to target groups.
- Extension activities to emphasise sustainable natural resource management including indigenous knowledge systems.
- Documentation, rationalisation and institutionalisation and popularisation of contemporary farmer innovations.
- Promote SHGs, producer groups and commodity groups in order to fill gaps in extension services at village level.

III

THE WAY FORWARD – A PLAUSIBLE AGENDA FOR THE FUTURE

(a) *Agricultural Education*

The quality of agricultural education is the most important determinant of quality

of agricultural research in the country, because all scientific manpower for agricultural research is supplied by the agricultural education system. With hardly any flow of scientific manpower trained in advanced countries to India especially towards agricultural research, supply of high quality manpower for agricultural research continues to remain the predominant task of agricultural education system. Hence, any meaningful discussion of strengthening agricultural research cannot afford to miss the agricultural education system. Agricultural education is, however, facing serious constraints of sufficient and right faculty, inadequate financial resources, and several others (Mruthyunjaya, 2012). Therefore, any grandiose plan for research and extension will not succeed unless agricultural education system is thoroughly overhauled. Agricultural education system in India is long overdue for critical appraisal with regard to the quality and relevance of its content to meet present day challenges, the mode of teaching, examination system, and feed-back mechanisms between education, research and extension, vis-à-vis manpower and infrastructure facilities in various public and private agricultural educational institutes. It has been noticed that the curricula and syllabi, the teaching methods and examination systems have become the toys in the hands of the decision-making authorities to play around, without any regard to the science of teaching, learning and quality control mechanisms and processes. Syllabus revision, changes in teaching methods, and examination system have become periodic rituals without any insightful, democratic discussion, and bottom-up analysis of the strengths and weaknesses of the existing system and the implications of proposed changes, by involving the students and teachers. The curriculum, teaching and evaluation techniques need to be aligned with the demands of agricultural research system.

A scientific education system must encourage arousal of curiosity and questions among students, and facilitate them to reflect on what they have learned in the class vis-à-vis the objective realities on the ground, rather than education being a content-delivery mechanism. The syllabus contents, methods of teaching and examination system prevailing in other countries should be critically reviewed for understanding their strengths and implementation. The agricultural education system must aim to produce not just graduates, but practitioners of science skilled not only in solving the production problems of the farmers but also with a thorough understanding of the political, institutional, socio-economic, cultural, and historical problems besetting Indian agriculture, and the traditional knowledge systems in agriculture. This will enable them to look at agricultural problems in a holistic manner not just as a production problem to be addressed by technologies alone. Such an understanding will make them scientists capable of formulating research projects and extension methods with relevance to the realities that will generate maximum impacts on agricultural productivity and profitability with minimal damage to the ecosystem.

(b) *Research*

Agriculture and the food system face significant challenges that require informed decision-making in the public policy arena and in the private sector. There are a number of challenges critical to the future of agriculture in India, including the overarching need to help feed the expanding population while meeting the demand for food and nutrition security. In the emerging epoch of anthropocene, strong feedbacks between environmental, social and economic systems are causing increased uncertainty and risks in food situation. Increasing frequency and intensity of interconnected crisis co-exist with increasing incompetence and complacency of research management. Often the research management system is fragmented and it is insensitive towards the upcoming crisis in agriculture and the natural ecosystems supporting agricultural production. Complacency and incompetency breeds human resource degradation, nepotism, and rent-seeking. The agricultural research system is in fact longing for a dynamic, far-sighted leadership in several domains and at various levels of hierarchy. Therefore, ensuring a dynamic leadership with a clear vision about the future challenges is the crucial task. More and more new issues that require research attention such as food safety, nutrition and environmental concerns, and climate change, as well as new fields of research, viz., biotechnology, nanotechnology, precision farming, and organic farming are emerging. Consequently, the total amount of research funds is being divided and fragmented into more, but smaller parcels across these emerging issues and new research fields. Therefore, it is necessary not only to step up the research investments significantly, but also to prioritise these issues and research areas carefully based on their impact on current and future productivity, as well as on the natural ecosystems. The research investments should be allocated based on these priorities.

It is necessary to effectively communicate the multiple roles and importance of agriculture to the governments at the centre and the states, the larger society and to the ecosystem as a whole. The popularisation of the importance of agricultural research should focus on high-visibility issues for the society such as human nutrition, human health and environmental health, as well as its indirect role in creating a harmonious society by ensuring food security. Further, the additional food production due to increased spending on agricultural R and D will ultimately lead to reduced financial burden of food subsidy on government. Therefore, the net public investments in agricultural R and D will, in fact, be lower than nominal R and D spending by the government. In addition to the direct economic benefits from agriculture, the indirect benefits such as landscape preservation, carbon sequestration, etc., need to be given adequate policy and research attention. It is essential to create a stakeholder-driven strategic plan to communicate the need and value of research, the importance of adequate funding and the value of the potential returns to society as a whole. Research on new and novel ways of providing agri-environmental services need to be undertaken under Indian context and ways of incentivising agri-

environmental services should be identified. A larger coalition of interests including farmers, agribusiness firms, civil society movements and environmental activists is necessary to win political support for a vibrant and dynamic agricultural research system. Some of the important suggestions for the pressing problems of agricultural research are summarised below:

- Place greater emphasis on organising research around broader issues rather than funding very narrowly focused, short-sighted and fictitious issues.
- Linkages and/or overlap between All India Coordinated Research Projects and other programmes on the same crop or similar themes need to be strengthened and dovetailed.
- End-user involvement in research prioritisation, mid-term evaluation and finalisation of research outcomes is essential to make the research programmes productive and purposeful.
- Periodic inter-institutional research workshops and discussions should be organised across SAUs, and between SAUs and ICAR institutes to share the current and future research, extension and educational programmes, and issues in research administration and extension activities. Such inter-institutional discussions are required to share experiences, success stories and cases of failures and the reasons thereof.
- Exploring new options to increase funding through new institutional and organizational arrangements such as public-private partnerships is essential. This would require a united vision by university and industry representatives.
- As pointed out in the ICAR's Vision 2030 document, social scientists should be involved in research priority setting. Social scientists—economists and/or extension specialists—should be posted in all agricultural sciences departments and research centres so that informed decisions are made on research project formulation as well as in evaluating the deliverables using economic tests.
- Dryland agricultural research should receive adequate priority, as drylands pose special challenges in increasing productivity and livelihood. As rightly emphasised by Raina (2006), there must be (i) a broader and more inclusive definition of knowledge and issues relevant to livelihoods in the drylands, and (ii) a new paradigm of institutional learning and change, where science and technology will become part of a wider coalition of actors, inputs and processes.
- Institutional learning is essential to ensure an ongoing, reflective assessment of past achievements and failures in the research activities. The lessons learnt shall be used to inform future decisions and directions so as to engender a culture of internal self-

reflection rather than external reviews. It will help participatory decision making and prioritisation and implementation of decisions.

- A common research management model should be developed based on modern science management, human resource management and information technologies and implemented at all universities and agricultural research institutes—ICAR and SAU system.
- Periodic capacity developments in one or two specific areas of frontier research must be made mandatory for scientists of all cadres.
- It is high time to put in place a set of good appointment practices (GAP) for appointing of top-level administrators and research managers starting from ICAR to SAUs. This should be applicable to a selection of scientists and faculty positions as well with a rigorous system of testing the research aptitude and skills of the candidates. The existing system of national level eligibility tests should undergo tremendous changes to ensure the qualitative improvements required for revitalising future agricultural research.
- Harness experienced human resource potential for mentoring: Given the significant increase in life expectancy, it is desirable to increase the retirement age for agricultural scientists so as to use the rich experience of senior scientists. Based on a system of rigorous and transparent assessment of past contributions and scope for further contributions, every departments in SAUs should appoint at least one or two emeritus professors from among the retirees so as to harness their rich experience for mentoring the middle-level and junior faculty members.
- It is necessary to engage the private sector with farmer-producers, consumers, ICAR institutes, State Agricultural Universities and NGOs to work on a unified agenda of identifying and solving regional agricultural production and value addition problems.

The contribution from private sector for biotechnology and molecular breeding is essential due to capital-intensive nature of the investments in these technologies, while public research investments should focus on non-patentable technologies such as crop management practices, new hybrids especially for dryland farming systems, food safety issues, low-cost machinery and implements, water management technologies, etc. The public research system should develop mechanism for institutionalising mutually acceptable procedures in order to forge new alliances with private and not-for profit research and extension organisations, which may address some of the key socio-economic issues such as food security and environmental quality. A study in China (Hu *et al.*, 2011) found that public R&D investments in basic and basic-applied research increase private R&D, but public R&D investments

in development research decrease private R&D investment. If the government wants to encourage private firms to increase their agricultural R&D investments, the government should reduce its investments in development research, particularly in fields where technology can be protected easily with intellectual property rights. Instead, these funds should be invested in basic and basic-applied research or in directly funding R&D conducted by private firms. The study specifically suggests that for countries like India, which are rapidly increasing their government research expenditure, rapid expansion of technology development spending could crowd out private sector R&D. If the goal of the governments is to increase private R&D at the same time as they are increasing public R&D, then the governments should invest resources in applied and basic agricultural R&D. The potential for collaboration between public and private sector research under different subject areas of research are summarised in Table 2.

TABLE 2. PUBLIC-PRIVATE DIVISION OF LABOUR AND POTENTIAL FOR COLLABORATION

Subject area (1)	Public (2)	Private (3)	Potential for collaboration (4)
Basic research	Very High	Low / Limited	Very high
Rainfed crops	Very high	Very low	Limited
Seed /biotech	Limited	High	Very high
Chemical inputs	Very low to low	Very high	Limited
Farm machinery	Limited	High	Very high
Resource management	Very high	Low	Low / Limited
Post-harvest and value addition technologies	Limited	Very high	Very high

(c) *Extension System*

One of the important lacunae in the current model of both research and extension is the absence or ineffectiveness of mechanisms and institutional arrangements for information-sharing across the wide spectrum of stakeholders, and a very narrow conception of extension. Extension-plus approach is the key to expand and intensify the delivery of agricultural technologies and know-hows to the farmers. Rapid developments in information and communication technologies facilitate this new approach in a big way. Farmers need information on a wide range of issues ranging from crop choice decisions to marketing, processing and value addition and hence the extension-plus approach implies a broad scope of service provision beyond technology transfer. In most circumstances, the current agricultural extension paradigm centres around provision of production know-hows to farmers rather than a holistic array of services and supports including price and weather forecast information, post-harvest operations including on-farm packaging and storage, marketing, etc. Facilitation of credit delivery should also form part of extension activities. Extension should be construed as a means by which farmers and other

agents directly involved in agricultural production and primary processing and storage should be educated on agricultural policies and their short- and long-run implications, collective actions required for resource and infrastructure management in agriculture, etc. (Glendenning *et al.*, 2010). The extension workers should not merely be a conduit for one-way delivery of technical know-how to the farmers, but a two-way channel connecting the farms to the labs, in the sense that farmers' problems and production constraints should be effectively summarised and transferred to the research system or the scientists. An institutional mechanism to represent stakeholders' interests at the management level is necessary, so that the extension programmes and the feedback mechanisms remain accountable to its stakeholders. Unlike the present model of extension system, efforts should be directed at utilising and building social capital through networking with adequate consideration of existing social dynamics, social networks, shared norms and informal institutions in rural areas. There is scope for taking advantage of network externalities in information dissemination if modern ICTs are appropriately combined with the existing social networks and ongoing efforts in building these networks for other purposes. Establishing seamless connectivity between various actors, programmes and stakeholders in agricultural and rural development is essential.

IV

CONCLUDING REMARKS

Systemic problems require systemic solutions, not window-dressing or fire-fighting. We live in an era in which a number of path-breaking technologies are being generated by the private sector, while public sector research is either stagnating or degrading due to the various reasons discussed above. A fundamental problem plaguing agricultural education, agricultural research as well as extension systems is nothing different from the problems confronting our social and economic life, namely policy disarray, rent-seeking behaviour, principal-agent problems, lack of long term vision and accountability, and inadequate understanding and appreciation of the importance of science and technology. Rent seeking, lack of accountability and perverse incentive structure are not the problems within the system but rather they are often imposed from outside the system. The incentive system and work culture that suit the needs and priorities of government departments or purely educational institutions cannot be mechanically applied to the universities / institutes with multiple-mandates of research, extension and education. Whereas in educational institutions, the teaching activities are mostly repetitions of the tasks previously done, and often more uniform in quantity and quality across space and time, while researchers search for solutions to a particular real world problem and the effort levels and outcomes vary to a great extent across scientists. The researchers are expected to continuously update their knowledge, skill and ingenuity to produce novelty with utility. It turns out that the administration and management of scientific

human resources including their service rules, financial management in the SAUs and research institutes, and performance yardsticks and incentive systems for scientists have to be completely revamped and science-friendly rather than being vague and subservient to vested interests. Appropriate incentive system that is capable of attracting researchers from advanced national level institutes and research laboratories as well as from abroad towards agricultural research in India should be developed and implemented with a specific time frame. More than anything else, it is absolutely essential to revamp agricultural education system and improve its content and form substantially so as to attract high quality students and transform them into agricultural scientists of impeccable quality dedicated to the welfare of the farming community.

The reasons for our inaction or muted response towards the serious problems afflicting agricultural education, research and extension are, in many dimensions, similar to the reasons for our inaction on climate change. Agricultural research is an impure, global public good with lots of cross-country, inter-regional and inter-institutional spill-overs. Further, the degradation in agricultural research system is slow and persistent, similar to climate change. Public perception and appreciation of the gravity of the problem is absent or grossly inadequate, and hence whatever policy attention agricultural research receives from governments are often mediated by short-term political compulsions—caused by food shortage and food inflation, farmers' suicides, elections, etc—rather than by long term vision and commitment. As we are presently in the comfort zone of sufficient food availability without the kind of crisis situation that was haunting us during pre-green revolution era, there is an all-around laxity in addressing the impending crisis in agricultural research and extension systems. No amount of macro-mode reforms such as research programmes in the name of NATP, NADP or NAIP, call it whatever, will not push the frontiers of scientific productivity unless the research climate, the quality of scientific manpower and their core competencies undergo revolutionary changes. Unless agricultural education, research and extension are nurtured through active and farsighted support from the Governments to reinvent and promote the old glory of research ethics and work culture, the pursuit of seeking solutions within the research system will continue to remain an empty rhetoric. In the absence of long term visioning and policy activism in support of public sector agricultural research and a missionary zeal to implement the far-reaching reforms, the public agricultural R and D will meet a crisis in the near future. It is eminently plausible to assume that changes will not happen overnight, and it is equally plausible to expect that nothing can standstill in front of powerful public campaigns and changing realities. Hopefully, sooner or later, changing realities and economic forces would compel policy makers to take credible and serious actions that will dispel the contemptuous undertone of Sowell's insightful statement that I have quoted in the beginning.

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