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PERSPECTIVES IN AGRICULTURAL RESEARCH AND DEVELOPMENT IN INDIA : SOME ISSUES FOR ANALYSIS AND DATA BASE

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It is indeed an honour and privilege to have been invited to deliver this year's Dr. Rajendra Prasad Memorial Lecture. After India emerged as the Sovereign Democratic Republic, the first citizen Babu Rajendra Prasad reflected the country's culture of high thinking, simple living and commitment to the villages.

Agricultural growth largely reflects rural growth and development. The near self-sufficiency in the food front achieved in two decades does provide us with a sense of pride and satisfaction. These past two decades reflect an important landmark in our agricultural history. We exploited diverse genetic resources and employed unconventional methods of experimentation and technology transfer. While these materials and methods have certainly been useful, there is growing thinking that further progress at the experiment stations is not as perceptible as it ought to be; that yield levels, in districts where technology transfer was concentrated, are not moving beyond a point which is far below the potential yields. A kind of yield plateauing or lack of perceptible advances at experiment stations and in potential districts has frequently been observed. We are yet to travel a long way to meet our future commitments and our materials and methods towards this end do need refinement and rennovation.

As statisticians, you value quantification and precision. Today all

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crop and animal improvement projects have the association of senior statisticians. There has been a growing feeling that the role of the statistician is primarily a service function. I have the conviction that statisticians have to play a significant role in quantifying and analysing issues, establishing research priorities, developing innovative methodologies, precisely estimating the progress in crop and animal improvement and providing the data base for further progress in research and development. It is difficult to draw a dividing line between statistics and economics since all issues eventually boil down to economics and need evaluation of the accruing benefits. I, therefore, thought it appropriate to use this opportunity to place before us a few of the issues concerning statistical design, economic analysis and the need for a data base and plead with you to deliberate upon your own role in shaping agricultural research, experimentation and development.

Present Status of Agricultural Production

It has been said that if the 260 million hectares of available land, which includes 143 million hectares of cultivated land, could generate an average income of Rs. 5000/- per hectare every year, the countryside would have 100,000 crores more purchasing power and would support faster industrial growth and provide employment for 60 million families below the poverty line. The potential for the several fold increase in productivity of our agriculture, forest and animal resources has been pointed out. Compared to the potential our accomplishments have been modest. A technological change for ecologically sustainable and income generating agriculture is still the major means if the present average farm incomes of Rs. 1,250/- per hectare and Rs. 30/- for forestry have to reflect quantum jumps.

After independence, the production of foodgrains grew from 50 million tons in early 1950's to over 150 million tons in about 35 years. This is certainly a quantum jump. The progress of production for various commodities is presented in Table 1.

Irrigation has been pivotal in deriving the advantages of the new seeds and fertilisers. An FAO survey indicates, if the irrigation targets are realised and the land is managed properly, India, by the end of this century could feed 2.5 times the estimated population of 1 billion. The potential for generation of income at higher levels in the irrigated sector and assured rainfall black soil belt are obvious.

The Ministry of Agriculture published the All India growth rates of important crops (Table 2) for the pre-green revolution period (1949-50 to 1964-65) and post-green revolution period (1967-68 to 1984-85). The improvement in productivity during the latter period has been modest

TABLE 1—PROGRESS OF PRODUCTION OF SOME AGRICULTURAL COMMODITIES IN INDIA (million tons)

	Commodity	*1950-51*	*1960-61*	*1970-71*	*1980-81*	*1985-86*
1.	Foodgrains	50.82	82.02	108.42	129.59	150.47
2.	Rice	20.58	34.58	42.22	53.63	64.15
3.	Wheat	6.46	11.00	23.83	36.31	46.89
4.	Coarse cereals	15.38	23.74	30.55	29.02	26.46
5.	Grain legumes	8.41	12.70	11.82	10.63	12.97
6.	Oilseeds	5.16	6.98	9.63	9.37	11.15
7.	Cotton (million bales)	3.04	5.60	4.76	7.01	8.61
8.	Jute (million bales)	3.31	5.26	6.19	8.16	12.73
9.	Sugarcane	57.05	110.00	126.37	154.25	171.68
10.	Potato	1.66	2.72	4.81	9.67	10.70
11.	Tobacco	0.26	0.31	0.36	0.48	0.44
12.	Coconut (million nuts)	35.82	46.39	60.75	57.20	66.20

TABLE 2—ALL-INDIA COMPOUND (TREND) GROWTH RATES OF AREAS, PRODUCTION AND YIELD OF PRINCIPAL CROPS IN INDIA DURING 1948-50 TO 1964-65 AND 1967-68 TO 1984-85

(A—1949-50 to 1964-65; B—1967-68 to 1984-85) (per cent per annum)

Crop	*Area*		*Production*		*Yield*	
	A	*B*	*A*	*B*	*A*	*B*
Rice	1.33	0.66	3.49	2.37	2.13	1.74
Wheat	2.68	2.58	3.99	5.70	1.27	3.04
Jowar	0.99	—0.73	2.50	1.92	1.50	2.67
Bajra	1.08	—0.83	2.34	0.92	1.24	1.55
Maize	2.66	—0.08	3.87	1.03	1.18	1.12
Ragi	0.84	0.41	3.08	2.40	2.22	1.99
Small Millets	—0.30	—1.93	—0.20	—1.52	0.09	0.41
Barley	—0.64	—4.75	—0.28	—3.25	0.36	1.56
Coarse cereals	0.90	—0.93	2.23	0.93	1.29	1.83
Total cereals	1.30	0.35	3.24	2.92	1.68	2.12
Gram	1.64	—0.50	2.66	—0.55	0.54	—0.08
Tur (Arhar)	0.57	1.17	—1.34	1.88	—1.90	0.70
Other pulses	2.07	0.79	1.28	0.96	—0.77	0.17

Total pulses	1.90	0.42	1.39	0.51	−0.22	0.19
Total foodgrains	1.41	0.36	2.93	2.68	1.43	2.14
Sugarcane	3.27	1.84	4.26	2.88	1.12	1.05
Groundnut	4.01	0.12	4.33	1.29	0.31	1.16
Sesamum	0.14	−0.42	−0.32	1.06	−0.36	1.51
Rapeseed and mustard	2.97	1.55	3.36	3.07	0.37	1.49
Seven oil seeds	2.64	0.44	3.34	1.91	0.13	1.45
Coconut	—	0.86	—	0.39	—	−0.46
Total oilseeds	2.69	0.34	3.11	1.75	0.20	1.29
Cotton	2.47	0.06	4.56	2.25	2.04	2.19
Jute and mesta	3.86	0.74	4.20	2.02	0.73	1.08
Total fibres	2.57	0.11	4.45	2.11	1.68	1.90
Potato	4.37	3.90	4.27	7.41	−0.11	3.37
Tobacco	1.66	0.20	2.79	2.43	0.96	2.24
Total non-foodgrains	2.52	0.75	3.54	2.60	0.93	1.43
All crops	1.61	0.46	3.13	2.66	1.30	1.91

and not adequate to offset the much slower increase in the area. The compound growth rate of agricultural production was 3.13% during the pre-green revolution period and 2.60% during the post-green revolution period. The desirable long term growth rate is 4.0%. It is only wheat and potato that have done well with respect to both production and productivity. But for the emergence of the non-traditional north-western states for rice production, the rice situation would have been even worse. Traditional rice growing states have not fared well. Amongst the rainfed crops only Jowar has done well with a compound growth rate of 2.67 as against 3.04 for wheat.

While crop adaptation and improvement could be looked in the context of agro-climatic regions, the state is the administrative unit. An inter-state analysis of rates of growth in foodgrains in relation to population growth (Table 3) reveals that in only five states—Maharashtra, Punjab, U.P., Haryana and Andhra Pradesh, food production kept pace with population growth.

TABLE 3—CLASSIFICATION OF STATES BY WEATHER-ADJUSTED RATES OF GROWTH IN FOODGRAINS PRODUCTION AND GROWTH IN TOTAL PRODUCTION : 1970-71 TO 1984-85

Positive Growth in production > Population Growth	*Positive Growth in Production < Population Growth*	*Negative Growth in production < Population Growth*
Maharashtra (6.23, 2.22)	Jammu and Kashmir (2.31, 2.54)	Kerala (−0.38, 1.80)
Punjab (5.92, 2.15)	Gujarat (2.07, 2.37)	Tamil Nadu (−0.64, 1.65)
Uttar Pradesh (4.32, 2.26)	Madhya Pradesh (1.95, 2.27)	
Haryana (3.90, 2.65)	Assam (1.90, 2.76)	
Andhra Pradesh (3.16, 2.06)	Orissa (1.59, 1.86)	
All India (2.70, 2.24)	Bihar (1.25, 2.18) Rajasthan (1.07, 2.87) Karnataka (1.03, 2.35) Himachal Pradesh (0.80, 2.10) West Bengal (0.54, 2.09)	

Notes: The figures in parentheses refer to growth rates (in percentages) of foodgrain production and population growth respectively. Population (rural and urban) growth is estimated from the 1971 census and Registrar General's estimates for 1985.

SOURCE : Mahendradev (1987).

The inter-state variation in fertiliser consumption (Table 4) is indicative of its selective use.

TABLE 4—STATE-WISE CONSUMPTION OF FERTILISERS

Sl. No.	*State*	*1984-85*	
		Total Consumption' (000 tonnes) (N + P + K)	*Consumption (kg) per hectare (N + P + K)*
1.	Andhra Pradesh	980.29	76.77
2.	Kerala	127.65	44.60
3.	Karnataka	590.68	52.97
4.	Tamilnadu	690.52	114.51
5.	Gujarat	504.56	49.52
6.	Madhya Pradesh	372.61	16.77
7.	Maharashtra	581.26	29.12
8.	Rajasthan	206.57	11.23
9.	Haryana	336.62	63.44
10.	Uttar Pradesh	1612.91	65.28
11.	Himachal Pradesh	21.75	22.70
12.	Jammu & Kashmir	29.07	29.00
13.	Assam	13.80	3.88
14.	Bihar	381.60	39.58
15.	West Bengal	405.73	57.93
16.	Manipur	3.76	20.00
17.	Meghalaya	2.90	13.96
18.	Nagaland	0.29	1.63
19.	Tripura	3.10	8.13
20.	Orissa	114.01	13.69
21.	Sikkim	1.20	11.61
22.	Punjab	1047.61	151.50
	All-India	8210.96	47.56

Similarly when we look at the growth rates of crop yields (Table 5). only Wheat, Jowar and ragi kept pace with the population growth rate.

TABLE 5—RANKING OF CROPS BY GROWTH RATES OF YIELD
(1967-68 to 1983-84)

Crop	*Growth rate*
Wheat	3.0
Sorghum	2.8
Finger millet	2.2
Cotton	2.0
Rice	1.6
Pearlmillet	1.5
Groundnut	1.2
Sugarcane	1.0
Maize	0.7
Pigeon Pea	0.4
Chick Pea	—0.2

SOURCE : Agricultural situation in India 1985.

Another aspect of production that received attention is the production instability studied by Mehra, Hazel, Mahendradev and others. These studies indicated that, generally, growth in agricultural production was associated with increased instability. The factors responsible for this instability have been analysed. Instability in production was not a general phenomenon in all areas and could be related to factors like rainfall, irrigation etc., (Table 6). Nevertheless growth with stability is important.

Thus, while fulfilling the immediate needs of our food which is the most significant contribution on the agricultural front, the green revolution technology which has been selective raised questions including equity, stability and sustainability.

Agricultural research perspectives and priorities have to take cognisance of the prevalent situations. The perspectives are not the same for all areas and regions. The priorities with respect to regions and commodities need critical evaluation. Investment decisions on soft infrastructure or hard infrastructure influence the outcomes. The continuous

TABLE 6—STATES CROSS-CLASSIFIED, 1960-61 TO 1984-85

Standard Deviation in Year-to-Year Changes	*Unadjusted Trend Rates of Growth*		
	High (more than 3.0 per cent)	*medium (2.0 to 3.0 per cent)*	*low (Less than 2.0 per cent)*
Low (less than 15 per cent)	Punjab, Jammu and Kashmir	All India, Andhra Pradesh, Himachal Pradesh	Assam, Kerala
Medium (15 to 20 per cent)	Haryana, UP	Karnataka	Tamil Nadu, West Bengal
High (more than 20 per cent)	Gujarat	Maharashtra, Orissa, Rajasthan	Bihar, Madhya Pradesh

SOURCE : Mahendradev (1987).

raising in the use of inputs to generate rapid growth in agricultural production, the economics and utility of alternative cropping strategies, the resource allocation and returns on investment are of vital consideration. The Australian workers in cooperation with the International Food Policy Research Institute have developed procedures for establishing research priorities at the commodity and regional levels. Several models are available for establishing research priorities for resource allocation to derive maximum benefits. A similar exercise on research priorities for our research system will be useful. I will now consider some of the issues concerning research, development and data acquisition.

Commodity and Area Oriented Researches

Agricultural research in this country started as a highly localised public enterprise, with some research stations established in agro-ecological nitches. The commodity committees, the Indian Council of Agricultural Research and the State Governments have given agricultural research largely a commodity orientation in the central as well as the state sectors. Problem oriented research stations such as those for salinity, floods, etc., came up in a limited way. In recent years, resource oriented research is receiving increased attention. The establishment of the National Agricultural Research Project is an effort in orientation of research towards agro-climatological zones and is still in the formative stages. Special ecosystems like the hill and mountain systems and island systems which remained backward are also getting attention.

To date the research that has paid quick dividends enabling the country to attain near self-sufficiency in a matter of two and half decades has been the commodity oriented high yielding varieties programme mediated by the All India projects. Its significance and contribution to the country's economy and its selective nature have been well documented.

With the success of this programme, the scientific efforts both in the Central and State sectors exhibited a greater shift towards applied variety oriented research because of the demonstrated dividends. These programmes were no doubt inter-disciplinary, largely oriented towards the development of improved cultivars and cultivar based package of practices. Both Central and State sectors participated through the medium of All India Coordinated Research Projects. While their immediate dividends were spectacular, subsequent progress has been rather slow and their influence on the research system as a whole has become a point for discussion. There is a feeling of stagnation and the States felt that the Co-ordinated Projects took away the initiative with consequent set backs.

In earlier years, Indian agricultural research contributions figured in journals like *Nature* and other journals of high citation index. The fundamental schools of research have now gone into the background. Some isolated efforts like the creation of chairs of eminence could not revive fundamental research to the extent desired. During the past few years, I had the opportunity to assess the scientific work of a large number of researchers from Central Institutes and also look at the University Research. It is an exception rather than a rule to come across high quality scientific work or publications. Outstanding individuals in a discipline or sub-discipline or commodity have become a rare occurrence in a country of this magnitude with such large number of scientists. I shall not go into the reasons, but the fact remains that basic research suffered both in the State and Central sectors.

Coming to adaptive research, outside the coordinated network, the major avenues for data acquisition are the various kinds of demonstrations including the minikits which no longer emphasise quantitative data, the National Demonstration Project largely oriented to irrigated crops in a limited area of operation, the Lab-to-land programme, the limited number of operational research projects and the Krishi Vigyan Kendras which are largely training oriented.

The data base for release recommendations of varieties or cultivation practices including input use largely emanates from the Centres of the All India Projects which at the level of each State is often very small. Adaptive research data on an area basis within a State are almost absent before a recommendation is made. This could be the primary reason why compared to the large number of releases, only a few stood the test of time.

The essence of this is that as far as applied and adaptive researches are concerned, the data base has become narrow, largely confined to the participating Centres in the Co-ordinated Project. With technology transfer programmes becoming largely training oriented, the minikits, lab-to-land etc., not being oriented towards data acquisition, analysable adaptive research data on single or multiple factor packages has become a rarity.

On the production side, the target fixation is commodity oriented. In our anxiety to meet the targets, we turn towards resource rich areas. The result has been that resources have gone again and again into the same commodities and generally the same assured areas. The production trends in some such districts have already shown logistic trends with yield plateaus occurring much below the potential yields. The reasons for such plateaus need critical analysis. Indications are available that lack of use of organics, heavy dependence on fertilisers like DAP instead of SSP, micronutrient deficiencies etc., could be the causal factors.

Currently, there is some area orientation to production programmes such as the special rice production programme in eastern India, but vast areas of the assured rainfall black soil belt extending from Deccan to Malwa receive scant attention in production programmes. Currently special production programmes are confined to 69 resource rich districts. I personally feel that there is a need to shift our emphasis from commodity based targets to area based targets and promote and monitor commodity production on an area basis. The applied and adaptive researches will then need an area orientation and the data base to be built upon the area basis. It is necessary to strike a balance between commodity and area oriented researches.

Current efforts at restructuring of agricultural research in the country emphasize basic and strategic research of national importance at the Central Agricultural Research Institutes, a reduction in the All India Coordinated Research Projects with cost sharing on equal basis with the State Agricultural Universities and regional research orientation at the SAU level. This restructuring should take care of the linkages between the Central, Coordinated and SAU researches in such a way that the researches reflect a holistic approach with a proper balance between (a) basic research, (b) commodity and area oriented applied researches and (c) adaptive research on an area basis. At this point of our agricultural development, it is only the proper balance between commodity research and the area orientation of both applied and adaptive researches that could further balance agricultural growth and equity.

The statisticians should attempt to develop the framework for data acquisition on an area basis for cultivar-resource responses and related aspects to link them up with production programmes. Once such a data base is established, monitoring of progress of research and its linkage with production becomes feasible. This is perhaps the only way if selectivity has to gradually yield place to equity in rural progress.

Wide Adaptation and Location Specific Research

The initiation of the All India Co-ordinated Research Projects in the 1960's is an important innovation in our Agricultural Research System. This provided for a network of Co-operative experimental stations and testing sites. Their association with international agencies like the Rockefeller Foundation, the International Maize and Wheat Research Centre in Mexico, the International Rice Research Institute in the

Philippines provided opprtunities to obtain global germplasm resources and improved versions of breeding materials for direct testing and further improvements. The testing of improved versions of exotic breeding materials furnished the initial basis for breakthroughs in yield levels and adaptability barriers giving rise to what has come to be known as the High-yielding Variety Technology. The earlier philosophy of adaptation and breeding for narrow nitches, narrow germplasm base and marginal yield advantages yielded to the use of diverse genetic materials and wider adaptation coupled with quantum jumps in yields. Our horizons on adaptation, germplasms, breeding and testing methods and yield levels have certainly expanded. The first improved high yielding varieties of wheat and rice, hybrids of Jowar and Bajra are examples of this kind. Subsequently, these varieties have been improved for quality and resistance attributes.

As the programmes expanded, crop adaptation zones based on agro-climatic features were demarked, Zonal Coordinators were identified and the crop improvement and testing programmes were largely confined within the zones. Release recommendations have also become zone oriented. And yet it is the widely adapted varieties that are being largely favoured by the farmers. Compared to the number of releases, those that are under cultivation are only a handful.

Recently, I had an opportunity to analyse this aspect of wide zonal adaptation with respect to several crops—wheat, rice, jowar, maize and mustard. This study was based on the common entries, few in numbers, in all the zones for each of the crops. The limited number of entries did impose a limitation on the study. The proportion of variability accounted by the zone × genotype interaction component varied from 1–5% only. In most cases, Zone was the most important component followed by years. This is understandable as yields of wheat or mustard decrease as they move South wards, but the zone × genotype interaction component was not large and superior strains maintained their relative superiority across zones. In some cases the genotype × year interactions were also low indicating their stability of performance across year to year fluctuations.

The wider testing across zones and years as practised earlier, enabled identification of larger genotype differences, eliminated more sensitive types and favoured genotypes that could stand a range of fluctuating agro-climatological factors. Wide adaptation, adaptability and high yield are not certainly negatively correlated and more stable genotypes could be identified. This is the reason why several varieties of wheat, rice, jowar etc., found superior on All India basis performed and adapted well in several other countries.

I should not be misunderstood as pleading for adaptation to all conditions or one variety across the country. The point I want to emphasize is the need for a critical analysis of the genotype × environment interactions through well planned experiments which could lead to testing procedures for identification of stable and superior cultivars. The need is for an efficient and discriminatory testing mechanism for cultivar or genotype differences.

While area based recommendations furnish the basis for technology transfer, wide testing has the advantage of identifying cultivars not only with greater yield advantage, but also greater levels of stability to withstand fluctuating growing conditions.

The discussion on adaptation also leads to the need for a more clear understanding of what is being called 'location specific research'. Limiting test material, avoiding testing in a wide range of locations, repetitive studies on fertiliser doses, spacings and other cultural practices do not alone constitute location specific research.

Most agriculture is practised under unfavourable conditions and the process of adaptation to such situations is now receiving increased attention. Plant response mechanisms to varying conditions indicate that specific processes are affected leading to genetic differentiation. Differences for nutrient absorption, responses to toxicities, water deficits and other adverse conditions do result and could be capitalized. Certain amount of location specific research gets into the realm of basic research and some problems in basic research need to be tackled on location.

Apart from studies on fertiliser levels, populations etc., which beyond a point tend to become repetitive, studies on agricultural systems, alternative cropping strategies and their long term use of inputs and input combinations, the monitoring of pests and diseases, cost effective integrated control strategies, advisory services to extension agencies and farmers etc., in a given area assume greater importance in the location specific area oriented researches. Some location specific research may involve the responsibility to carry out relatively simpler adaptive research studies by the researchers on cultivators' fields of the area.

Jodha who initially advocated more location specific research for the dry land agriculture later pleaded for a reduction in location specification of dryland technologies. He indicated that resource centred research around watersheds where boundaries of individual holdings cross and with increasing small holdings and with the fluctuating ecological conditions in dryland agriculture, broad based technologies are likely to have greater utility.

There is a need to more clearly define what is being called location specific research both at gross and fundamental levels and furnish an experimental framework. This will enormously help the National Agricultural Research Project immediately.

The need is for a synthesis and balance between wide adaptation with area specifics. The framework and experimental approaches for basic, applied and adaptive researches need to be designed with this objective in mind.

Cost Reducing Technologies

Increased input costs, demand-supply factors and prices affect cost-benefit ratios. Successes on the food in several countries including India have largely been accomplished due to subsidies on farm inputs. Increased agricultural output must result in the face of rising costs and not merely by increased investment. The major means has to be technological change.

Genetics and possibly bio-technology would provide the most important means for cost reduction by incorporation of inherently high yields, resistance to insect pests and diseases, responses to inputs and abilities to tolerate various kinds of stresses.

In favourable environments, the abundant resource approach to crop production is predictable and could yield economic returns. Agriculture is often practised under unfavourable and risk prone environments and the cost factor will determine the agricultural practices and the conservation approach becomes more meaningful. In such situations plant types which are productive with low inputs are more readily favoured.

While the national priorities may set targets for production of different commodities, the individual's interest will more frequently be in generation of more income. With near self-sufficiency and availability of subsidised food from the public distribution system, the tendency will be more towards maximizing farm income. Under small farm circumstances, maximization of welfare sometimes assumes priority over profit maximization.

Recommendation of suboptimal doses of fertilisers and other inputs is not the solution. Other alternatives need to be compared and economically evaluated. Comparative economic analysis of the alternative farming technologies oriented towards resource poor farmers of different agro-climatic regions is not available.

Some examples may be considered : (a) A few years back a pure crop or hybrid sorghum or hybrid bajra was more paying than the traditional inter-cropping. With rising costs of pulses and oilseeds, a hybrid based inter-cropping system with leguminous oilseeds or pulses has become more profitable. The proportions need to be standardized and evaluated for optimal income generation. (b) Similarly, in better rainfall areas, hybrids could be followed by a second crop of safflower or gram. (c) Another example : In irrigated areas, resource poor farmers are finding multiple cropping to be more feasible and profitable than the resource intensive sugarcane. (d) Another case could be a medium-long staple desi cotton with less plant protection, which is more profitable and less risk prone than American cotton hybrids requiring higher levels of inputs. (e) In drought prone areas, an agro-forestry system may be more profitable in the long run compared to the risky annual crops.

Experimental designs and comparative economics of alternative cropping/farming systems for various regions are yet to be developed and evaluated and the statisticians could play a significant role both in design and analysis of such studies. A shift from crop to a cropping system will be more cost effective in several situations.

There is considerable emphasis on watershed based dryland farming which is cost intensive. The design of experiments for evaluating alternative cropping strategies with long term economic studies under the watersheds need critical attention. Under certain topographic and the prevailing soil and rainfall conditions, less cost intensive alternatives may be more rewarding.

Data are now being generated on alternative uses of agricultural commodities, use of by-products and agricultural wastes in the rural sector to provide agro-based employment and income generation.

A holistic approach for multiple factor analysis in terms of cost-benefit ratios and social benefits deserves attention.

Growth with Sustainability

Agriculture will continue to be practised under unfavourable conditions. Not only arid and dryland agriculture but irrigated agriculture also will be subject to climatic aberrations and calamities which would cause production instability. The years 1972-73 and 1987-1988 are recent reminiscences of severe drought. The sub-Saharan drought of Africa has been very well analysed with its climatological, sociological and technological dimensions and was well documented. In our country inspite of these severe calamities, scientific documentation in all its aspects has not received the due attention. A proper documentation of such events will provide the basis for long term amelioration other than immediate relief through subsidies, supplies, services and compensations. Documentation of abnormal situations should deserve our attention.

The long range sustainability of agriculture through resource management and conservation has become urgent. Soil, water, forests and atmosphere are the basic life support systems. The management of land and water resources is now receiving increased emphasis.

The major factors for production instability have been analysed. The inter-crop and inter-state covariances and the year to year fluctuations in area apart from others have come out as major factors. Sustainability involves policy, administrative and technological attention. Researches leading to technological approaches have been limited and some of them have been discussed earlier.

Modelling in various areas which affect production has not received the attention that it deserves in our country. It has been illustrated through modelling that for a given production with reduced S.D. and C.V. certain crops grown in certain areas will exhibit less fluctuation. This is only illustrative and more work could be done to carve out efficient crop zones. Modelling of resource use, modelling of climate and modelling of dryland ecosystems are potential areas of study.

On the technological side, breeding of less risk prone varieties, development of less risk technologies, efficient management of supplies and services for a stable input use, pest management without excessive dependence on pesticides, capacity to foster diversification in agriculture, contingent plans—have all been mentioned and have relevance. But when it comes to practice we have to-date relied on assured areas and abundant resource technology.

Agriculture under unfavourable circumstances should receive better attention.

Technological Change

A technological change is a change in the production function and is a relation between inputs and outputs. Based on emerging technologies, technological forecasting helps to chart out the future course of development. The accuracy of predictability has considerably increased due to a better understanding of the kinds of systems and their interactions and the use of newer statistical tools and techniques. These include extrapolative and intuitive (Delphi) techniques, morphological designs and diffusion times—the time required to translate a technological finding to ultimate production.

The country will be getting into the frontier areas of technology like biotechnology in agriculture. This is no doubt vital for the growth of agricultural science.

Electronics and computers will have impact on agriculture. Control of irrigation, planting, fertilisation, pesticide application and a large number of operations can be accomplished by coupling to sensors. Better information systems will influence agricultural business. Agricultural engineering could have greater impact in future. The future is for dealing with several interacting systems. Constraints on land, water and energy use would require an ability to shift agricultural production systems to more reliance on science and technology and greater human skills. The approach to analyse the technological change will itself be a challenge.

Our present average production levels of most commodities are very low (Table 7) and a two to three fold increase is feasible with conventional approaches. In realising this and shaping future agricultural research, the statisticians have to play a vital and innovative role and furnish the framework and the data base for an equity oriented technological change. I plead with you to deliberate on these and related issues and participate in the design of technology, its evaluation and forecasting.

TABLE 7—ALL INDIA AVERAGE YIELDS (1984-85)

Crop	*All India Average Yield* (kg/hectare)	*Range* (kg/hectare)
Cereals		
Rice	1,417	759-3,073
Wheat	1,870	866-3,288
Jowar	715	495-859
Bajra	569	321-1,119
Maize	1,456	1,231-2,450
Pulses		
Gram	661	396-926
Arhar	819	224-1,619
Oilseeds		
Groundnut	898	531-1,549
Mnstard	771	386-1,225
Soya Bean	768	715-856
Cotton	196	87-447
Sugarcane	57,673	33,425-1,03,801