INDIAN AGRICULTURE AT THE CROSSROADS*

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INTRODUCTION

I AM grateful for the privilege of being asked to deliver the Tenth J.N. Tata lecture. J.N. Tata was known both for vision and action. Where vision is limited, action is equally circumscribed. In a lecture instituted in the memory of a great visionary, it will be useful to discuss the future of our agriculture, since ours is primarily an agricultural country with land and water-based occupations providing most of the jobs in addition to food and income. The most challenging task ahead for a country of our population size and structure is to win the battle against the famine of work.

In the developed countries, the new wave of technological change spearheaded by automation and computerization tends to displace labour from its traditional position as the dominant factor of production. Adoption of this pathway will make our rich human resource a liability than an invaluable asset. The challenge of unemployment can be met only by developing agriculture and rural occupations in a scientific manner. If farming does not lead to expanded internal and external trade, the desired degree of diversification of employment opportunities will not occur in rural and urban areas. Without diversified income earning opportunities, the plight of marginal farmers and the landless poor will become worse as population increases. Most calculations show that over 70% of our work force will have to depend upon agricultural and rural professions for their living until the end of this century.

The importance of land and water-based occupations involving agriculture, horticulture, animal husbandry, fisheries, forestry and agro-industries in providing not only food but also jobs and income cannot, therefore, be over-emphasised.

What is the crossroads we have arrived at in agriculture? On several earlier occasions I had stated that our country can either become a major bread basket of the world or take to the begging bowl to meet our food requirements depending on the nature of public policies adopted and community endeavour generated. In a recent book on "International Trade in Grain and the World Food Economy" by Bastin and Ellis[1], the choice before us in wheat has been stated as follows:

"The USDA model highlights the position of India as a wheat producer of global significance. According to one set of assumptions, the country could be importing 8.6 million tonnes of wheat in 1985, making it the world's largest single wheat importer. According to another alternative set of assumptions, India could be exporting almost 5 million tonnes of wheat in 1985, making it one of the largest wheat exporters."

Should we take to the 'import' or 'enhanced home production' pathway for meeting our requirements of foodgrains, sugar, edible oils and cotton? In my view, the "import pathway" in agriculture, even if we can afford it, will take us to a serious "famine of work" leading to an accelerated migration of rural poor to urban areas seeking jobs. By import pathway. I do not mean occasional imports necessitated by natural factors but making imports a habit to make good for inaction at home. What action points will mark the difference between these two pathways of development? To answer this question, it would be useful to trace briefly the nature of our agricultural evolution during this century.

OUR AGRICULTURAL EVOLUTION DURING THIS CENTURY

For the sake of convenience, I would like to recognise three major evolutionary phases. The first phase, extending from 1900 to 1950, was a period of stagnation in our agricultural and rural economy. The average growth rate in agriculture during this period was about 0.3%. Agricultural stagnation meant rural stagnation and this in turn led to the drain of both brain and resources from the village to the town. The neglect of rural areas was so great that at the time of Independence, most villages did not have even one source of safe drinking water. Even now we have nearly 2,30,000 villages which are yet to be provided with potable drinking water. Stagnation also meant that no attempts were made to provide any form of commercial energy in support of agricultural occupations. Even today, the farm sector which provides nearly 40% of the export earnings and sustains over 70% of the population, consumes only about 10% of the commercial forms of energy (Table 1). Thus, the contribution of this sector to our economic well-being is immense, considering the insignificant investment of resources and energy.

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TABLE I*

Relative Shares of different forms of Commercial Energy for various sectors in 1978-79

(in percentage)

Sector	Energy Form			Percentage of total commercial energy consumption
	Coal	Oil	Electricity	
Household	10·0	71·2	18·8	13·7
Agriculture	0·0	61·8	38·2	10·6
Industry	44·5	7·9	47·6	38·5
Transport	13·3	83·9	2·8	31·7
Others	11·9	36·2	51·9	5·5

*Source: Report of the Working Group on Energy Policy, Planning Commission, 1979.

Whenever agriculture failed due to unfavourable weather, famine conditions prevailed. This is why, considerable thought was given in the pre-independence days to the development of Famine Codes and Scarcity Manuals. Above all, colonial rule tended to freeze social evolution. There was total social failure in the field of redistribution of agricultural assets like land and livestock and in the prevention of exploitation of primary producers at both the production and post-harvest phases of farm operations.

The second phase of our evolution covering the period 1950 to 1980 was one of growth in the development of the infrastructure necessary for the modernisation of agriculture. The outmoded land tenure system at last received some attention, resulting in a gradual elimination of the zamindari and other intermediary tenures. Impressive progress took place during this period in developing powerful instruments for technology development, technology transfer and technology sustenance. The Indian Council of Agricultural Research, the network of Agricultural Universities and several associated institutions in the country provided an effective mechanism for carrying out location-specific research and for developing appropriate technologies to suit different agro-ecological, socio-economic and socio-cultural conditions. Technology transfer mechanisms included the development of extension networks supported by input delivery systems. For sustaining agricultural advance, policy and operational instruments such as the Agricultural Prices Commission and Food Corporation of India were developed.

We can see three distinct trends during the period 1950-80, in terms of programme development. The first major step in promoting accelerated agricultural advance was taken in 1961 when the Intensive Agricultural District Programme (IADP) was initiated. This programme was designed to maximise the production in areas endowed with irrigation facilities. Later, the introduction of high yielding varieties of seeds was superimposed over the area approach, since the earlier strains did not respond to higher levels of nutrition and irrigation. Through this step, the missing link in the package programme (IADP), namely genetic strains which can respond well to the rest of the package, was provided. The area approach was also structured to meet specific ecological conditions like drought-prone, hill and desert areas. The area and crop-centred approaches, however, were found to be inadequate for the purpose of enabling the economically handicapped sections of farmers to take to new technology. It is this lacuna which was attempted to be remedied through the introduction of special programmes for small and marginal farmers, agricultural labour and tribal people. Thus, gradually, an individual farmer-cum-a specific area model of programme development was born.

Infrastructure development during the period 1950-80 has been particularly impressive in the fields of agricultural research and education, irrigation, fertilizer production and in the storage and distribution of grains. Credit systems for the rural poor were also improved. As a result of the various steps taken during this period, the growth rate in agriculture rose to about 2.8% per annum, thus keeping slightly above the growth rate in population. Also, land use patterns which were predominantly based on the home needs of the farming family tended to shift towards market requirements.

We have now entered the third and the more challenging phase of agricultural evolution. Thanks to the infrastructure for modernisation developed so far, a higher proportion of farmers have something to offer to the market. Consequently public policies in the field of post-harvest operations have assumed great importance. Also, growing disparities and unevenness in agricultural progress between regions, crops and farmer categories are creating various kinds of tensions and distortions. The rapid growth in population resulting in increasing fragmentation of holdings is making the size of farms smaller and smaller. The size of an operational holding has now reached about one hectare in States like Uttar Pradesh and Bihar (Table II). Therefore, the number of families which have to make a contribution for achieving a specific production target is increasing. The size of the landless labour population is also growing. While in a state like Punjab, foodgrain production increased between 1960-61 and 1978-79 by 8·01% per year, this growth was only 1·19% in Orissa. The annual growth rate for total agricultural

TABLE II

State-wise average size of operational holdings for 1970-71 & 1976-77 as per agriculture Census

(Hectares)

Sl. No.	State	1970-71	1976-77
	Group I: Land Records States		
1.	Andhra Pradesh	2·51	2·34
2.	Assam	1·47	1·37
3.	Bihar	1·5	1·1
4.	Gujarat	4·11	3·71
5.	Haryana	3·77	3·58
6.	Karnataka	3·20	2·98
7.	Madhya Pradesh	4·0	3·60
8.	Maharashtra	4·28	3·60
9.	Rajasthan	5·46	4·65
10.	Tamil Nadu	1·45	1·25
11.	Uttar Pradesh	1·16	1·05
	Total Group I	2·49	2·18
	Group II: Non Land Records States		
12.	Kerala	0·57	0·49
13.	Orissa	1·89	1·60
14.	Meghalaya	1·7	1·5
15.	West Bengal	1·20	0·99
	Total Group II	1·26	1·04
	Group I & II (11+4) States	2·30	2·00
16.	Himachal Pradesh	1·53	1·65
17.	Tripura	1·02	1·20
18.	Manipur	1·15	1·2
19.	Nagaland	5·40	7·61
20.	All UTs except Mizoram	3·14	2·78
	Total 16–20	1·99	2·16
21.	Punjab	2·89	2·74
22.	Jammu & Kashmir	0·94	0·94
	Total 21–22	2·08	2·03
	Grand Total 1 + 22	2·28	2·00
23.	Sikkim	..	2·56
24.	Mizoram	..	1·49
	Total 23-24	..	2·28
	All India Total	2·28	2·00

production for Punjab during the period 1952-53 to 1969-70 was 6.6% as against 0.7% for Bihar. Minimising regional disparities and extending the benefits of new technology to all classes of farmers, therefore, become areas of priority concern.

Another major issue facing us now is the whole area of land reform and agrarian structure. Land reform has so far been mainly looked at from the point of land ownership, land ceiling and security of tenure. For enabling small and marginal farmers to produce more, land reform will have to be given an ownership-cum-production interpretation covering steps which will facilitate the more efficient use of land. For example, without land consolidation and levelling, it becomes difficult to manage water properly and thereby derive full benefit from our investment on irrigation. Human and animal demographic pressures on land are now threatening basic life support systems like soil, flora and fauna. The Himalayan ecosystem, for example, which sustains over 150 million people, is threatened with ecological disasters. While nature takes anywhere between 100 to 400 years or more to generate 10 mm of top soil, it has been calculated that nearly 1.4 million km^2 of our country are now subject to various forms of soil erosion. Sedimentation as a result of careless use of watershed forests is endangering the economic life of reservoirs, hydroelectric facilities and irrigation systems. Diminished quantities of irrigation water finally lead to smaller command areas and loss of food production. Recent surveys have shown that the storage capacity of Nizamsagar lake in Andhra Pradesh was reduced by 63% in 44 years; of Mayurakshi and Maithon reservoirs by 10% in 20 years; of Panchet reservoir by 12% in 19 years and of Bhakra reservoir by 6% in 16 years. In almost every case the originally estimated life of the reservoir will need re-assessment. Floods ravage the Indo-Gangetic plains almost every year taking their toll in terms of human life and property. Because of poor soil structure and alkalinity, the infiltration of water in the soil profile is poor. Consequently, several flood-affected areas tend to become drought affected soon after the recession of floods and withdrawal of monsoon. Hence land reform in our country should include steps not only relating to the equitable distribution of available land resources among all sections of the rural community but also measures such as consolidation of holdings, land levelling and soil health care which are essential for the sustained agricultural productivity. Agriculture being primarily a solar energy harvesting enterprise is the most important source of renewable wealth. There will, however, be no difference between agriculture and sources of non-renewable wealth, if the renewable base of farming is destroyed, as is happening in several parts of our country.

Another important question facing us now is the need for looking at problems relating to the cost, risk and return structure of the agrarian economy in an integrated manner. Thanks to the availability of new technology and additional sources of irrigation, more and more farmers are using their land, not only for satisfying their home needs but also market requirements. Thus today more farmers have something to offer to the market. When farmers invest more on purchased inputs, the best fertilizer to them is assured together with remunerative marketing. Market reform hence becomes an urgent necessity, so that the gap between what the producer receives and the consumer pays gets minimised to the utmost possible extent. Market reform is often not possible without credit reform since the merchant and the money-lender frequently is the same person. Crops thus get automatically bonded when farmers have to take loans from money-lenders for purchasing production inputs. The whole area of post-harvest technology relating to transport, marketing, pricing, storage and distribution thus assumes great importance. Where there is a mismatch between production and post-harvest technologies, neither the producer nor the consumer gets benefit from increased production. This is why we now witness various forms of both farmers' unrest and consumers' agitations.

Under conditions of small farms, the net "take home" income of the farmer is very small. The risks become correspondingly greater when input costs are high. For example, in our country the price of nutrients has been going up (Table III). Fertilizer prices have increased by about 62% during the past 15 months. What should be our input-output pricing policies? Should input cost be kept high and should farmers be compensated by a higher procurement price? In my view, it is more important that inputs are subsidised and output price kept low, so that consumption levels can be improved, Since there is no crop insurance worth the name and since farming is the riskiest profession in the world, the poor farmer will not be able to derive benefit from the new technology based on purchased inputs, if the price of these inputs is kept high. A majority of our farmers also live in dry farming areas. The soils in such areas have been described as even more 'hungry' than 'thirsty'. Soils in dry farming areas hence respond well to nutrient application. When fertilizer prices are high, balanced fertilization becomes a casualty. If the average productivity is to be improved, more farmers will have to have the capacity to purchase good seeds, fertilizer and appropriate forms of commercial energy. It is not with reference to crops only that we need a rational input-output pricing policy. Animal husbandry provides opportunities for providing supplementary income to the rural poor. Here again farmers are facing difficulties due to a doubling in the cost of feed during the last seven years. In contrast, the cost of egg has not risen by the same margin, although 80% of the cost of production goes to the cost of feed. Since we import edible oils and other farm products which we can and should grow in our villages, there is a tendency to export feed grains and proteins for animals to earn foreign exchange, although we should really be using them for enabling landless labour families to take to poultry rearing and other animal based occupations.

The current phase of our agriculture is hence highly dependent on public policies for its success or failure. Community co-operation and endeavour will be the other major requirement. Under conditions of small and fragmented holdings, it becomes essential that farmers carry out some aspects of farm operations such as water management, plant protection and post-harvest technology on a watershed basis. Fertilizer use

TABLE III

Physical Returns on Wheat and Paddy 1971-72 and 1981-82 (11-7-1981)

(Data compiled by the Fertilizer Association of India)

Particulars	1971-72	1981-82 11-7-81	+% 1981-82 over 1971-72
I. Paddy			
1. Kg. of paddy required to buy 1 kg. of N (through Urea)	3·79	4·87	28·5
2. Kg. of paddy required to buy 1 kg. of P_2O_5 (through DAP)	3·51	5·55	58·1
3. Kg. of paddy required to buy 1 kg. of K_2O (through MOP)	1·68	2·07	23·2
II. Wheat			
1. Kg. of wheat required to buy 1 kg. of N (through Urea)	2·64	3·93	48·9
2. Kg. of wheat required to buy 1 kg. of P_2O_5 (through DAP)	2·45	4·48	82·9
3. Kg. of wheat required to buy 1 kg. of K_2O (through MOP)	1·17	1·67	42·7
Nutrient Prices (Rs./Kg.)			
1. Urea	2·01	5·11	154·2
2. DAP	1·86	5·83	213·4
3. MOP	0·89	2·17	143·8
Output Prices (Rs./Kg.)			
1. Paddy	0·53	1·05	98·1
2. Wheat	0·76	1·30	71·1

TABLE IV

Estimated average fertilizer consumption per hectare and yield of wheat in some selected States (1971-72 to 1974-75)

(Data of ICAR)

State	Area	Irrigated area (million hectares)	Fertilizer consumption (kg/ha)				Yield kg/ha	Response in kg/kg of nutrient
			N	P_2O_5	K_2O	Total		
Uttar Pradesh	6·05	4·14	21·8	5·3	3·6	30·7	1,148	5·6
Punjab	2·35	2·07	58·3	18·7	4·7	81·7	2,307	15·4
Haryana	1·19	1·00	38·8	4·2	1·8	44·8	1,770	18·4

efficiency, for example, varies a great deal depending upon the level of management. In the Punjab and Haryana, application of one kg of nutrient to wheat on the average gives a respose of 12–15 kg of grain. However, in Uttar Pradesh the increase in yield was only 4–5 kg per kg of nutrient until a few years ago (Table IV). Due to lack of appropriate community action, we find that the efficiency of water use is not as high as it could be and also the intensity of cropping is much below the desired levels. Plant protection is poor due to the absence of an area approach in land use, planning and pest control. In black soils, water logging and other soil health problems arise. Above all, poor soil and water management and inadequate soil health care are tending to make the dividing lines between flood and drought narrow. Thus we have entered a stage of agricultural evolution where more detailed attention will have to be given to the co-operative organization of farmers and farming, to the management of both the production and to post-harvest phases of agricultural operations and above all to the public policy package essential for increasing production as well as consumption. While dealing with these issues, I would like to refer briefly to the emerging trends in world agriculture.

PATHWAYS OF AGRICULTURAL DEVELOPMENT: SUPER FARMS AND SMALL FARMS

The world today is witnessing two contrasting trends of evolution of farm ownership and management systems. In terms of ownership, the land may be either socially or individually owned. In both, free enterprise countries like the United States, Canada and Australia as well as in socialist countries like the USSR, Eastern Europe and China, the size of an operational holding is getting larger and larger. In contrast, in many of the developing countries of Asia and Africa, the size of a farm holding is tending to get smaller and smaller. We can thus recognise, on the one hand, large super farms exceeding 1,000 hectares in size based on capital and energy intensive and labour displacing technology, and on the other, small farms of 2 hectares and below operated largely with family labour and with very little capital or energy investment.

SUPER FARMS

Among super farms, three broad categories can be recognised:

(a) U.S. Model: The United States today serves as a major bread basket of the world. A good example of the trend in U.S. farming methodology is provided by the rice culture operations in California[2]:

"The production of rice in California has evolved into one of the most highly mechanized agricultural operations in the world, including the levelling of fields by laser beam, the sowing of seed by airplane and the harvesting of the crop by special combines that do not bog down in the mud of the rice paddy. The 1979 California yield of 6,450 pounds of rice per acre was 50% higher than the average in the other rice-producing States in the U. S. and nearly three times higher than the world average of 2,360 pounds per acre. Although the acreage devoted to rice in the U.S. is only 0.9% of the world total, the U.S. produces 1.7% of the world crop and in many years is the world's largest rice exporter."

Super farm management technology of this kind is based on a heavy consumption of non-renewable forms of energy. In this system, energy consumption is high not only in the production phase but also in the post-harvest phase of the production-consumption chain. Serious thought is hence being given to the methods of reducing the high dependence on fossil fuels in achieving productivity improvement. For example, a study conducted on agricultural production efficiency by a Committee of the U.S.

National Academy of Sciences showed that modern cropping systems in the United States yielded less than 5 calories of digestible energy per total calorie of agricultural energy. Out of various systems studied, the most energy efficient agricultural systems were labour-intensive vegetable growing in New Guinea and rice culture in the Philippines[3]. However, these comparatively efficient cropping systems were also the least productive in terms of digestible energy per heactare. In other words, the pathway of productivity improvement chosen in the super farm management system involves an exponential rise in energy consumption.

(b) Soviet Model: The Soviet model of super farm operations largely consists of big State-collective farms. Since land is socially owned, a collective farm is run like any other State enterprise. The farms are highly mechanised and because of weather conditions in the USSR, energy consumption in these farms also tends to be very high. Many developing countries have also experimented with such large mechanised farming methods. We in India have a few large State Farms started with the help of USSR. These are mostly used now for seed production.

(c) Cooperative agro-industrial complexes: The third kind of super farm model is the one found in several Socialist countries in Eastern Europe like Bulgaria. This involves the organisation of a large contiguous area into an agro-industrial complex. Each agro-industrial complex has a land use model based on considerations of economics and ecology. Production, processing and marketing are linked together into an integrated system. The Complex provides the needed facilities to the farming families who are members of the cooperative which manages the complex. Land is not individually owned but the members of the complex have a sense of belonging because of the institutional devices introduced for promoting cooperative management of farm operations. Other Communist countries like China have also introduced cooperative systems of management of farm operations within a framework of social ownership of land.

Thus the super farm organisation of agriculture is assuming different manifestations based upon the land ownership pattern, *i.e.*, private *versus* State ownership. Whatever the administrative or ownership structure may be, the super farm operation provides opportunities for introducing scientific management systems such as the following:

1. Crop planning in accordance with agro-meteorological and soil-moisture-retention data on the one hand and marketing opportunities, on the other;
2. Minimum or appropriate tillage;
3. High plant density leading to dense crop canopies;
4. Weed-free environment;
5. Controlled release of fertilizer, use of nitrification inhibitors, foliar feeding and use of low cost, anhydrous ammonia;
6. Use of bacterial, algal and other microbial fertilizers;
7. Integrated nutrient supply involving an appropriate blend of organic, inorganic and biological sources of fertilizer;
8. Better on-farm management of water, including drip irrigation in arid land;
9. CO_2 fertilization for maximising production in glass houses;
10. Integrated pest and disease management involving crop sanitation and agronomic, genetic, biological and chemical methods of control.
11. Use of hormones and growth regulators in fruit trees and ripeners in sugarcane;
12. Organic recycling leading to crop-livestock, crop-fish, and crop-livestock-fish integration.

The super farm technology can also generate the necessary resources to overcome problems arising from risk and return and can help in efficient marketing. However, this kind of farming also faces a few major problems:

(a) high consumption of non-renewable forms of energy;
(b) environmental pollution arising from the application of large doses of chemical fertilizers and pesticides; and
(c) problems of motivation and soil productivity maintenance under conditions where the individual or firm has no long term stake in the land.

Confidence has been expressed by several experts that the energy-intensive super-farm technology could be reoriented gradually towards a zero-energy farming system. For example, Leach[4] describes what can be done in North America and Western Europe as given below:

"The energy-intensive Western farmer could, with little trouble, reduce his overall energy consumption dramatically—and without any loss of yield or return to labour-intensive methods. Recycling animal wastes partially to replace artificial fertilizers, or using them to generate methane, are two frequently urged solutions since they solve the sometimes critical waste disposal problems too. But by far the largest impact would be made by using sensibly a natural fuel that many farmers now burn wastefully and destructively in their fields—cereal straws.

Most farms grow cereals. An average acre of cereals in the U.K. yields roughly one ton of straw with a gross energy value of 3 million kcal (2,000 kcal/lb, 30% moisture content in the field). This is roughly equal to the *total* energy input per acre for most farms, and is more than twice the energy used per acre as fuel and electricity for all farms except pig and poultry enterprises. Preliminary work at Nottingham University shows how this straw might be harvested and turned into a fuel for a very low energy cost. The entire cereal plant is cut with a forage harvester (instead of a combine for the grain plus a tractor and cutter-baler for the straw) and dried. After drying, the grain and straw are separated, and the straw could be burned either in a furnace to provide heat for drying, or in an external combustion engine (e.g. Stirling cycle) to provide mechanical power or even electricity. The straw drying would consume about 12 to 15 gallons of fuel (600,000 to 700,000 kcal) under average conditions, giving a net energy yield of 2·3 to 2·4 million kcal. Alternatively, the straw could be fermented (without drying) to a liquid fuel such as alcohol with a net energy yield of around 1·5 million kcal/acre plus by-product material for feeding ruminants. This last figure equivalent to 36 gallons of diesel fuel, is higher than the liquid fuel consumed/acre for all farms except pig and poultry, and is over 50% higher than the consumption for dairy and cereal farms. With a judicious mixture of fermentation. and direct straw-burning, including burning to generate power, and with animal wastes providing methane or nitrogen, phosphorus and potassium, it seems entirely probable that many farms might become self-reliant for all fuel and power, and would need to import energy only in the form of some fertilizers, machinery and other technical equipment, and sprays."

The super-farm free-enterprise technology is not without its own socio-economic problems. A recent study on the causes which led to farmers' protest in the State of Kansas in the United States indicates that uncertain farm prices in a time of inflating farm costs is tending to get farming resources concentrated into fewer hands and thereby lead to a decline of the rural economy and society. This study also showed that while farmers of Kansas State were ideologically committed to "the free market concept", they favoured such non-market solutions as target prices, favourable loan rates, production controls and collective bargaining[5]. The primary need of the system was identified as an yearly orderly marketing programme.

Under the large mechanised farming operations, the profit per farmer will obviously be high. For example, according to USDA, one American farmer feeds 56 people and by this yardstick the American farmer can be stated to be most productive. But when we measure productivity in terms of land or capital or energy, this superiority is no longer true. This is where small farms have both an advantage and an opportunity.

Small farm development is also taking place in different directions. More than 90% of all tropical farms are less than 5 hectares in size. National averages in Asia are often less than 3 hectares. Land is mostly individually owned. Because of erosion and top soil loss, the nutrient status of many soils in the tropics and subtropics is not favourable for high productivity. The highly skewed rainfall pattern makes the land not only hungry but also thirsty during large parts of the year. Thus low soil fertility, poor soil structure, low energy input, poor seed, uncertain water availability, extreme temperatures, lack of access to inputs and markets, all reduce the productivity of small farms in the tropics and sub-tropics. However, under conditions where land is limiting, very highly productive and energy efficient systems of farming have been developed during the last 20–30 years. Japan, Taiwan and North and South Korea have all reached high levels of productivity in crops like rice under small farm conditions. China has also reached an average yield level in rice of over 3 tonnes per hectare in an area exceeding 30 million hectares. Although land is socially owned in China, the density of farming population is high. Systems of cooperative management, particularly of irrigation and plant protection, have helped in ensuring a high average yield. High yields of cotton have become possible in Egypt under small farm conditions through the introduction of collective management of farm operations, like plant protection within the confines of individual ownership of land. Data collected from selected villages in Asia show that there is no significant difference in the average yield of rice per hectare between large and small farmers adopting modern varieties except in Indonesia. These data are consistent with the hypothesis of scale neutrality of new technology. Ruttan[6] after a review of the available micro-level data in Asia concluded "neither farm size nor tenure has been a serious constraint to the adoption of new high yielding varieties" and "neither farm size nor tenure has been an important source of differential growth of productivity."

Harwood[7] has, in a recent book on "Small Farm Development", dealt with the various factors which are involved in improving the productivity of small holdings. For achieving productivity improvement under small holders' conditions, there is need for developing institutional structures which can promote collective or group management of certain farm operations like water management, plant protection and post-harvest technology, without affecting the individuality of ownership. If this does not happen, there will always be co-existence of certain unique farmers who produce very high yields while at the same time the average productivity of the area is very low. In other words, the challenge lies in making the unique into universal.

Helping Small Farmers

Even at the currently available levels of technology, the gap between potential and actual farm yields is high in most small holdings. The reasons responsible for this gap will have to be identified in every area through an interdisciplinary constraints analysis. While the small farm offers potential for intensive agriculture the small farmer faces numerous problems arising from the cost, risk and return structure of farming. Only by helping the small farmer to overcome the problems facing him, can the potential productivity of small farms be realised. Several steps will have to be taken to assist small farmers to improve their economic conditions by raising the profitability of farm operations as well as security of income. A few such steps are described below:

Organisation of Land Use Boards

In order to help in re-structuring land use patterns on scientific lines, it would be desirable to organise Land Use Boards with high-level inter-disciplinary expertise. Each Board can cover a specific agro-ecological area. Such Land Use Boards should assist farmers in optimising the economic benefits from cubic volumes of soil, water and air through attention to the following major ingredients of scientific land and water use:

(a) Ecology: Land use based on ecological considerations will help to maximise the economic benefits from a given environment and minimise damage through man-made as well as natural processes of damage to the biological potential of land. Agro-meteorological research data will have to be integrated in crop planning models, so that contingency plans suited to different weather probabilities can be prepared. Also, an action-reaction analysis will have to be done in irrigation projects not only to avoid salinization and waterlogging but also the spread of new vector-borne diseases which impair human productivity and efficiency.

(b) Economics: For reorienting land and water use on the basis of sound principles of economics, it is essential that production, storage, processing and marketing are viewed as a total system. The prevailing mismatch in many farming systems between these two areas of the production-consumption chain is harming both producers and consumers. High risks and uncertain returns prevent poor farmers from investment on cash inputs and thus the asset base of the farm remains sub-optimal from the point of view of productivity improvement. The scope for introducing insurance and other forms of protection will have to be investigated by the Land Use Board in order to stimulate the widespread adoption of scientific agriculture. The various possibilities in the field of crop insurance have recently been summarised by Ray.[8] When post-harvest technology is neglected, opportunities for the preparation of value-added products are lost. For example, food production statistics simply state that during 1978-79 India produced about 131 million tonnes of foodgrains. This ignores the fact that the plants represented in this statistics produced over 400 million tonnes of dry matter, out of which grains constituted about 131 million tonnes. If the entire biomass is viewed as an asset and is utilised effectively, new avenues of income generation can be opened up. By looking at the dry matter yield part by part and by introducing techniques of preparing value-added material, rural incomes can be enhanced.

(c) Energy: The energy needs of agriculture will have to be carefully worked out and an integrated energy supply system involving a suitable blend of renewable and non-renewable forms of energy will have to be introduced in each agro-ecological area. So far the pathway of productivity improvement has tended to rely heavily on a growing consumption of non-renewable forms of energy. We will have to reverse this process through the promotion of organic re-cycling techniques and through the wide-spread use of biological sources of fertilizers like *azolla*, blue green algae and symbiotic and non-symbiotic forms of nitrogen fixing organisms. Also the current tendency to cultivate energy-rich crops like grain legumes and oilseeds under conditions of energy deprivation has to be corrected. "Nitrogen farming" should become an integral part of farm technology. Phosphorus conservation and re-cycling will be particularly important since phosphorus is a non-renewable resource. These steps will be facilitated if the farmers in each area organize "Renewable Energy Associations" and adopt a scientific energy conservation, generation and utilization methodology.

(d) Employment: Famines in India are often famines of work than of food, since when work can be had and paid for, food is always forthcoming. The situation today in the field of nutrition is one of providing the wherewithal to purchase food rather than just the availability of food in the market. All estimates of employment potential show that a majority of our people will have to depend upon agriculture, agro-industries and small-scale industries as the major source of income until the end of this century. Hence the employment impact of land and water use policies needs to be studied. The impact on the employment opportunities for rural women should receive specific attention in all development programmes.

(e) Nutrition: Each Land Use Board should have on its staff a nutrition scientist who could help to meet

nutritional criteria in land use patterns. This would help local communities to improve the level of nutrition through steps such as:

(i) Preparation of home-made weaning foods;
(ii) Providing some critical missing nutrients in the diet, like Vitamin A, Vitamin C, iron, etc.;
(iii) Developing a cereal-grain-legume combination so that all the essential amino-acids can be provided in the diet;
(iv) Introducing appropriate fodder legumes and shrubs which could provide the needed calories and proteins to farm animals, thereby enabling the introduction of larger quantities of animal food, like milk and milk products, eggs, etc., in the diet;
(v) Developing suitable agriculture-cum-aquaculture techniques which could help in promoting dietary combinations, like rice-fish, potato-fish, etc.; and
(vi) Promoting agro-forestry systems of land management where appropriate botanical remedies to the specific nutritional maladies of the region get incorporated.

A majority of our farmers have less than one hectare of land to cultivate. They have to meet their own food requirements and, in addition, should have some surplus produce for sale. An important method of obtaining supplementary income in such cases is the integration of animals in the farming system. It is necessary that suitable technologies are developed for preparing fortified feed material from all cellulosic wastes and from agricultural raw material. Fortification of straw with molasses and urea as well as microbiological enrichment of starchy material, like cassava will have to receive much wider adoption.

(*f*) *Crop-Weather Watch*: State and Central Land Use Boards will have to possess the capacity to advise farmers on the scientific handling of different weather situations. An inter-disciplinary crop-weather watch Group should be an integral part of the Board. With the help of the India Meteorological Department and Agricultural Universitites, this Group should give continuous advice to farmers on:

(i) Risk aversion and crop life saving techniques;
(ii) Contingency plans to suit different weather conditions;
(iii) Compensatory programmes in irrigated areas.

Techniques for mitigating the effects of floods and drought are now available. For example, in the drought affected areas of the U.S. in 1980, it was found that plots subjected to chemical tillage retained more water and gave nearly normal yields.

Rural Development

Rural development in the ultimate analysis involves the provision of opportunities for the optimum utilisation of the human resource in rural areas. Human resource development in its turn can take place only on the foundation of adequate nutrition and work opportunities. It is, therefore, necessary to base rural development programmes on the primary aim of providing opportunities for the human population to achieve optimum expression of their physical and mental potential. Such programmes should have the following four major components:

(a) Economic emancipation of the family with particular attention to provision of adequate employment opportunities to women who are largely engaged at present in unpaid and underpaid jobs, often characterised by physical drudgery;
(b) Education of children and adults;
(c) Provision of minimum needs, such as safe drinking water supply, health care, rural communication, etc.; and
(d) Promotion of a small family norm through population and contraceptic education.

Experience with programmes such as the "Food for Work" and the "National Rural Employment Project" of the Government of India and "Employment Guarantee Scheme" of the State Government of Maharashtra has provided useful insight into methodologies for nutrition improvement and rural infrastructure development. For example, the Employment Guarantee Scheme of Maharashtra has revealed that there is predominance of females in 52 out of 87 selected works. The female participation was on an average 57% in many rural works programmes. A similar observation has been made in several areas where the "Food for Work" programme has been in progress. The fact that women will have additional income and, in the case of "Food for Work" programme, will also receive directly foodgrains has an important implication from the point of view of nutrition of children. Thus, carefully designed rural development programmes which can generate diversified opportunities for employment and help to provide adequate nutrition will hasten agricultural advance.

Systems Approach to Research and Development

Mixed farming involving crop-livestock integration and mixed cropping involving the simultaneous cultivation of two or more crops in a field and multiple cropping leading to taking 2 to 4 crops per year in the same plot of land are possible in the tropics and sub-tropics. In the past, both research and developmental efforts were organised more on the basis of individual crops or farm animals. We now know that what the farmer needs is advice and assistance relevant to the entire farming system around which the lives of the farmer and his family revolve. Fortunately an awareness of this need is now growing. Some of the major farming systems which require attention in this respect are the following:

(a) Multiple-cropping systems in irrigated areas: Various two-, three- and even four-crop sequences are now being followed. In promoting multiple-cropping systems, attention should be paid to ensuring that grain and fodder legumes find a place in the rotation. Also, crops having the same pests and diseases should not be grown in succession. Introduction of grain and fodder legumes in the rotation will improve human nutrition as well as soil fertility. A mung-bean-rice-wheat rotation is a good method of combining cereals and legumes in north-west India. Short-duration varieties of pigeonpea (*Cajanus cajan*) have made pigeonpea-wheat rotation possible. A jute-rice-wheat rotation is becoming popular in parts of Assam and West Bengal in India as well as in Bangladesh.

The introduction of relative insensitivity to photoperiod and temperature through breeding has been responsible for the development of 'period fixed' rather than 'season bound' varieties. For purposes of breeding varieties for multiple-cropping, per-day yield has to be used as a selection criterion in segregating generations. Also, other factors such as seed dormancy will need attention, since if a crop ripens before the monsoon rains have ceased, the grain will sprout if there is rainfall at harvest time.

(b) Rain-fed farming: Production possibilities in high-rainfall areas are similar to those in irrigated areas. However, in the unirrigated semi-arid areas commonly referred to as dry-farming areas, considerable production risks exist. Grain legumes, sorghum, millets, cotton and oilseed crops are mostly grown in such areas. A wide variety of fruit trees can also be grown. Research thrusts in semiarid areas should lay stress on water and soil conservation and land use planning based on precipitation, evapotranspiration and the moisture holding capacity of the soil. At the organisational level, watershed management and the introduction of *Varabandhi* or rotational distribution of water saved in farm ponds will be necessary. Contingency plans should be developed and introduced so as to minimise the risk of total crop loss during aberrant weather. Seed and fertilizer reserves will have to be built so as to make the adoption of alternative cropping strategies and compensatory programmes in irrigated areas possible. It is also necessary to find more profitable crops for some of the semi-arid areas. There are many under-exploited plants with potential economic value.

(c) Mixed cropping and intercropping: Various crop combinations are used by farmers, particularly in unirrigated areas, but not all are scientifically sound. Therefore, intercropping systems based on complementarity between the companion crops have to be developed. Among the major components of complementarity are: (i) efficient interception of sunlight; (ii) ability to tap nutrients and moisture from different depths of the soil profile; (iii) non-overlapping susceptibility to pests and diseases; (iv) introduction of legumes to promote biological N-fixation and increase protein availability.

(d) Multi-level or three-dimensional cropping: In garden lands where a wide variety of plantation crops, fruit trees, coconut, oil palm and other tree crops are grown, it is possible to design a crop canopy in which the vertical space is utilised more efficiently. Plant architects will have to take into account the effective use of both horizontal and vertical spaces when breeding varieties for use in three-dimensional crop canopies. Efficiency in such a cropping system will again be based on the extent of the complementarity generated among crops in the system. For example, studies have shown that coconut, cocoa and pineapple form a good combination from the point of view of efficient interception of sunlight and extraction of nutrients and moisture from different soil depths. Studies of the root system of companion crops are of particular importance. The introduction of grain and fodder legumes in these three-dimensional crop canopies will provide opportunities for animal husbandry. A careful study of all the major garden land cropping systems based on the extent of symbiosis and synergy among the system components will be useful in developing specifications which plant breeders can use in developing ideotypes (i.e. conceptual plant types) for efficient performance in three-dimensional crop canopies.

(e) Kitchen gardening and home fish gardening: Kitchen gardening can be one of the most efficient systems of farming from the point of view of solar and cultural energy conversion. Vegetables rich in beta carotene and iron need to be developed and popularised. If planned intelligently and scientifically, backyard gardens, roof gardens and other methods of growing vegetables and fruits in whatever space is available around mud huts as well as brick houses can make a substantial contribution to improved nutrition. Where ponds are available in large numbers, home fish gardening can be an excellent method of supplementing income and source of food.

(f) Forestry and agro-forestry: The importance of improving the productivity of forest canopies cannot be over-emphasised. Agro-forestry has been defined as a sustainable management system for land which increases overall production, combines agricultural crops, tree crops, forest plants and/or animals simultaneously or sequentially. Sylvi-pastoral, sylvi-horticulture, sylvi-agriculture and other combined land-use systems can help to meet the food, feed, fuel and fertilizer needs of people in many hilly regions. Plant breeders have yet to give attention to breeding

varieties suitable for such systems of sylviculture. Shrubs and trees suitable for raising energy plantations in villages need to be identified and popularised.

(g) Mixed farming: Mixed farming systems may involve (i) crop-livestock; (ii) crop-fish, and (iii) crop-livestock-fish production programmes. In Kerala and Eastern India, fishing in rice fields is common. The minimal use of pesticides will be important in order to avoid problems of fish mortality and transfer of toxic residues through the food chain. This will involve maximum use of genetic resistance and the development of integrated pest-management systems in crops like rice and jute.

(h) Sea farming: There are considerable opportunities for the spread of scientific sea farming practices involving an appropriate blend of capture and culture fisheries. The rate of growth of oysters, mussels, prawns, lobsters, eels and a wide variety of marine plants and animals is high in tropical seas. If along with such integrated sea farming practices, the cultivation of suitable economic trees like casuarina, cashewnut and coconut can be popularised along the coast, thriving coastal agriculture-cum-mariculture systems can be developed. In addition to improving income and nutrition, such farming systems can help to arrest coastal erosion.

Constraints anaysis and Removal

Agriculture starts moving forward only when an appropriate package of technology is supported by suitable packages of services and public policies which can help all farmers irrespective of the size of their holding and their innate input mobilising and risk taking capacity to take to new technology. For identifying the precise constraints which are responsible for the prevailing gap between potential and actual farm yields, it is necessary to conduct an inter-disciplinary constraints analysis. To be meaningful, such a malady-remedy analysis will have to be done in compact areas with similar farming systems and socio-cultural factors.

As mentioned earlier, an important constraint under conditions of small holdings with individual land ownership is the difficulty of achieving a high level of farm management efficiency. For example, if two neighbouring farmers adopt totally divergent approaches in the field of pest control, the farmer who wishes to achieve high levels of production may have to resort to a larger number of sprays of pesticides than would otherwise have been necessary. Hence a challenge to development planners and administrators dealing with small farm conditions lies in introducing suitable packages of services which can help to introduce a community/area approach in management wherever this is necessary.

For optimum efficiency, a blend of cash and non-cash inputs will be necessary. Such services are best provided by farmers' own organisations supported by appropriate training, credit and marketing assistance from Government. The organisation of community nurseries in crops like rice where transplanting is done, the introduction of rotational distribution of water in the command areas of irrigation projects so that all farmers in the command area get equal quantities of water and the supply of credit and the needed inputs before the sowing season in properly organised credit-cum-input supply village fairs, are examples of the approaches which have been found useful.

Learning from successes is equally important in programme formulation. If Punjab made striking advances in crop production after the release of dwarf varieties of wheat and rice it is because the State already possessed the substrate requirements essential for new technology to find widespread adoption. Three of the major technology diffusion substrate needs which Punjab possessed in mid-sixties were: owner cultivation, rural communication and rural electrification. Roads and energy supply are exceedingly important inputs.

Basic Building Blocks of the Enhanced Home Production Pathway

The two key requirements in this respect are: first, *organisation* of small farmers both for improving farm management efficiency through community action in water and soil conservation and management, pest control and post-harvest technology and for ensuring that the producer gets a high proportion of the price paid by the consumer; secondly, a well-planned programme of *diversification* of employment and income generation opportunities in rural areas so that a part of the farm labour can get absorbed in the secondary and tertiary sectors. This will call for a more detailed planning of the scientific utilisation of local resources, so that value-added products can be prepared from all agricultural raw material and suitable small and village industries promoted. Institutional devices such as the organisation of Horticulture and Aquaculture Estates, on the lines of industrial estates, will have to be promoted. Farmers' Service Societies operated by rural youth will have to be fostered.

Given the above steps, I am confident that the small farm technology can, on the one hand, acquire the strengths of the super farm methodology and at the same time avoid the difficulties in terms of social, ecological and energy costs, inherent in the super farm procedures. Making small farmers acquire the strengths of super farm cultivations, while avoiding their weaknesses, is thus a major challenge to agricultural technologists and planners working in

India. If this task is successfully accomplished, it will be possible to raise the average productivity of all farming systems and thereby help the country to derive benefit from its vast untapped production reservoir. Our two major resources are sunlight and the human population. These two resources can be linked in a symbiotic manner through green plants. When this is done on an extensive scale, we can bid farewell to the import pathway of meeting our needs of basic agricultural commodities.

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CHROMOSPHERIC EMISSION INTENSITIES AND STELLAR EVOLUTION

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An age dependence of chromospheric emission intensities, especially for stars on the main sequence, has been known for some time.[1,2] These observations of intensity measures of the resonance lines of ionized calcium in the spectra of known members of the well known galactic clusters, the Pleiades and the Hyades, have shown the subtle difference in chromospheric flux caused by a difference in ages of the two clusters. Indeed, the intensity criterion has been used effectively by Kraft and Greenstein[3] to identify faint members of the Pleiades cluster from the background of field stars. Skumanich[4] has placed this relation on a quantitative basis by using flux values, reduced to a common spectral type, of the Sun, and also the Hyades, Ursa Major and Pleiades groups. An emission decay that follows the inverse square root of age is found, a pattern that is closely similar to that exhibited by rotational decay along the main sequence, as well as by the curve for lithium depletion.

The association of Ca^+ emission intensity with longitudinal magnetic field has been a well-established correlation for surface features on the Sun. Frazier's study[5] of the emission flux in a band 1·0 Å wide demonstrates the validity of a linear dependence on surface magnetic field strength to measureable low values. Viewed in this context the net chromospheric emission flux is an index of the average surface magnetic field of the star. The proportionality to the rotational braking curve indicates a decay with age of the "dynamo" processes responsible for the surface fields. The chromospheric emission characteristic assumes a new role in our understanding of the subtleties of association between several phenomena that originate over nearly the stellar radius and beyond.

The integrated radiation from the Sun as a star displays a weak Ca^+ emission component that can be seen with the high dispersion instruments of present-day stellar spectroscopy. Three contributors to this flux of radiation are the bright mottle, the Ca^+ network with its aggregate of mottles resolved and unresolved, and the plage that locates an active region.[6] The bright mottle of size 1000 km, in the solar case, is the principal contributor to the integrated radiation. It has been shown[7] that the Sun follows the Wilson-Bappu relation essentially because of the dominant characteristic of the bright mottle. The bright mottle has a range of intensities; its mean characteristic profile and total mean radiated flux are correlated with the luminosity of the star and its age. A substantial variation in the mean mottle flux comes about only over a large time-scale, when the general parameters of mean mottle brightness decays; the present indications are that the general surface magnetic field is a major controlling factor of the brightness.