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SARDAR PATEL MEMORIAL LECTURES, 1973

OUR AGRICULTURAL FUTURE

by

DR. M.S. SWAMINATHAN

Director-General
Indian Council of Agricultural Research

at

INDIA INTERNATIONAL CENTRE, NEW DELHI

October 30, 31 and November 1, 1973

ALL INDIA RADIO, NEW DELHI

As for co-operation, I have cited a few instances of its power. In 1945, when the buffalo owners of Kaira District went to Sardar Patel to complain about their marketing difficulties due to exploitation by milk merchants, he replied that the obvious solution to this problem was to organise the dairy industry on a co-operative basis. He further advised the farmers to set up their own dairy processing unit. This was the seed for the growth of the Kaira District Co-operative Milk Producers' Union, which has brought prosperity to the formerly helpless owners of one or two buffaloes and has become a model for all parts of the country to emulate.

Our political freedom depends on rapid economic growth and this in turn depends on our performance in agriculture. The future of our agriculture in its turn depends on the success with which we can help the small and illiterate farmers to take the many small steps which alone can lead to a great agriculture. Science can only show the way; it is for us, the educated and the privileged class, to provide the will.

Jai Hind !

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set of examples which were valid at that time. We should not make the mistake of rejecting the principles because some of the examples used by Gandhiji forty years ago may be out of date in the light of modern science. On the contrary, science and technology have in their search for a productive agriculture compatible with human growth and human welfare, uncovered the very same principles which Gandhiji arrived at by a different route. If we can take the steps necessary to evolve the kind of agricultural system I have described so far, based on the most advanced principles of biological science, we can probably claim to have developed a Gandhian Agriculture, because this would be an agriculture where Gandhian concepts become manifested in the form of an advanced rural economy, benefiting all sections of the community.

To achieve this, the tool has to be education, and the chosen method, co-operation. Social synergy has to be released by using appropriate educational and organisational methods as catalysts. In addition to official extension agencies, we have numerous workers belonging to the Gandhian and Sarvodaya movements, missionary groups, voluntary service societies and others, who are dedicated servants of the rural poor, struggling with zeal and devotion to transform the face of rural India. What they lack are the tools and the understanding of a modern agricultural technology which can help them to achieve their aims.

Transferring technology to the masses

The technology is now becoming available but the mechanism for transferring it to the illiterate and small users in an effective manner does not exist. Ironically, there is a global communication network which makes the latest findings of science available almost immediately to research workers in any corner of the world ; but what is urgently needed is such a communication network at the service of the poor farmer in our country. It is not only knowledge that is needed, but an approach which will be able to supply the right knowledge and tools to the right people at the right time and place. The worker on the spot, whether he is an agricultural officer, a teacher, a gram sevak or a social worker, must be able to identify the local problem or need which will act as a catalyst for promoting co-operative endeavour in that area—it may be lift irrigation in one place, dairying in another, pest control in a third, supply of farm machinery or fish fingerlings in a fourth and marketing in a fifth. In this network, the mass communication media, particularly the radio, television, cinema and the language press, have a very important role to play ; so have the research and the extension worker, the education system and the drive for technical literacy.

In an earlier lecture in this series, Dr. Zakir Husain explained how we could tailor education to the needs of economic reconstruction.

The Tudiyalur Co-operative Society has been providing total service to about 8000 cultivators in the Coimbatore district. The Syndicate Agriculture Foundation, Manipal, the Mahatma Gandhi Lift Irrigation Co-operative Society, Gaddipalli, Kerala Development Society, the Musahri Plan initiated at the suggestion of Shri Jayaprakash Narayan, Food and Marketing Centre, Jamshedpur, the Agricultural Institute at Kosbad Hill, Shri Shivaji Council for Education and Extension, Godegaon, the Samanway Vidyapeeth, Bodh Gaya, Kishore Bharti, Hoshangabad, and several other organisations in different parts of our country are helping to uplift the economy of the poor. Various missionary organisations have been actively involved in educational and developmental work in the field of agriculture. The Aurobindo Ashram at Pondicherry runs a farm based on recycling principles.

The Archbishop of Trivandrum, for example, has personally tested and popularised new varieties of tapioca, hybrid napier grass and other strains popularised on a large scale. Our Rashtrapati, Shri V.V. Giri, in his integrated scheme on land colonisation has given a detailed outline as to how the benefits of agricultural transformation can be transmitted to educated unemployed youth on the one hand and landless labour on the other. Such colonies could become centres of generation of social synergy. All these examples need to be multiplied as fast as possible. This can be done, provided at the village level there is a combination between those who possess technical knowledge and those who are devoted to social service and both together identify the most important need of the village in getting its economy moving. If the need is correctly identified, and then properly attended to, it will act as a catalyst in releasing synergy. An important task of social workers is hence the identification of catalysts which can bring home through tangible economic benefits the value of co-operation to the small and marginal farmers.

I have so far spoken about an agriculture in which the ecological advantages of the different parts of our country can be maximised and the hazards minimised through appropriate land and water use planning, in which high synergy crop and animal production systems are introduced, recycling procedures used to promote a high growth rate in productivity on the basis of renewable resources of energy, farm and factory are closely linked, maximum economy and efficiency effected in the use of all resources, export markets nurtured through continuous attention to the changing quality needs of the clients and a fair and remunerative return assured to the primary producer. This is an agriculture based on ecological awareness, in which synergy, harmony and economy are the basic principles, and of which recycling is a tool. These are in essence the principles on which Mahatma Gandhi developed most of his concepts of rural reconstruction, though he used a different language and a different

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Our Agricultural Balance Sheet : Assets and Liabilities

Food is a basic requirement in the hierarchical needs of man. The successful domestication of plants, animals, soil and water by settled human communities has hence been the starting point for the evolution of culture and orderly Government. Sardar Patel often stressed this fact by emphasising that the only culture he understood was agriculture. Ironically, the very centres of civilization, where the domestication of plants and animals took place in the past, are the areas which are struggling today to find an honourable equation between population growth and food supply on the one hand, and population growth and opportunities for productive and remunerative employment, on the other. The secondary and tertiary centres of origin of agriculture have, in contrast, more than enough to eat and constitute the developed or rich nations of the world. It has been estimated that in the poor nations, which have contributed most of the domesticated plants and animals to the world, nearly 800 million individuals, live under conditions of absolute poverty, resulting in protein-calorie malnutrition, squalor, illiteracy and disease. Again, ironically, the lands of the poor have often greater biological assets, the most important of which is abundance of sunlight throughout the year, rendering the historic concept of cereal inapplicable. This word refers to crops which grow during only part of the year, being derived from the myth of Ceres' happy seasonal reunion with her daughter. In our earth, appropriately compared to a spaceship by Buckminister Fuller, the first class compartment, which the rich nations as well as the rich of the poor nations occupy, is consuming a greater and greater proportion of the available resources, thereby making life for those living in absolute poverty more and more hard. Those living in the first class compartment of the spaceship have forgotten the meaning of the prayer "God, give us our daily bread", while for the vast majority of humanity squeezed into the small second class compartment, "God is bread", to use the words of Mahatma Gandhi. Why are we in this state of paradox ? Why do plants seem to be unhappy and hence not so productive in their historic native homes ?

Contrasting trends

The state of food and agriculture in the world shows two contrasting trends. In one kind of agriculture, larger and larger farms are being farmed by fewer and fewer cultivators. Such farms are highly automated and capital-intensive. Let me cite an illustration. A recent article on computerized farming in California tells how a firm called Superior Farming Company, owned by a Texas Oil Company, raises 26 different crops on about 6,000 hectares, with land and equipment worth about Rs. 30 crores. In this agri-business, an irrigation system, called the drip method, brings individually piped water to every fruit tree and regulate the flow to a trickle, supplying exactly what each tree needs and no more. Under such systems of farming, not only is the efficiency of use of inputs like water and fertilizer high, but labour productivity also is very high. In one study conducted during the mid-fifties, it was found that while in many countries of Asia and Africa about 2.5 to 10 work days were needed to produce one quintal of grain, the extent of labour time needed to produce the same quantity of grain was about 3 hours in parts of France and only 6 to 12 minutes in parts of the United States. The gap in the relative productivity of farm labour was therefore about 1 to 800 even over 15 years ago and this gap, which also represents the relative earning and purchasing power of farm labour, has been growing ever since.

In many of the poor nations, including our own, smaller and smaller farms have to be cultivated by the same or even larger number of farmers. The percentage of work force employed in farming in India was 72.1 in 1971 and it is anticipated that this percentage will remain practically unaltered in 1981. The relative productivity of small farms, however, varies widely in the world. Mr. R.S. McNamara, President of the World Bank Group, pointed out recently that "if Japan could produce 6,720 kg. of grain per hectare on very small farms in 1970, then Africa with its 1,270 kg., Asia with 1,750 kg. and Latin America with 2,060 kg. per hectare have an enormous potential for expanding productivity".

Agricultural growth

Besides farm size and land and labour productivity, the other two major differences in the agriculture of the rich nations as compared to the poor ones, are in the pattern of agricultural growth and the nature of the food chain. The mechanised and low-labour consuming agriculture has achieved increased productivity largely on the basis of a high consumption of energy derived from the non-renewable resources of the earth. Thus,

strives to maximise the success of the group. Some of the approaches I described earlier, such as encouraging children and students to take up economic projects in a responsible way, and linking them with academic success, would be good examples of social synergy at work.

This is not however the only means of achieving the goal. In a free economy, it is possible to conceive of a system whereby farmers could be motivated to produce what the nation considered necessary. This would involve a very complex set of arrangements including pricing, availability of inputs, technical knowledge, land ownership and a variety of other things. However, it is clear that slogans and appeals to the social conscience cannot work, except for short periods during national crises. 'Grow More Food' or 'Self-reliance' are not adequate as methods to persuade farmers even to grow anything, leave alone to do so in an ecologically balanced manner. It requires a far more widespread and dynamic movement of society to bring about such changes. In other words, it requires a release of synergy.

I have been talking about individuals and society. It may be asked who is the 'Individual' whose interests have to be identified with the social interest? Whom is the new technology to serve? The first task is to identify the individual. I will begin by stating the obvious. The farmer of India, who must be served by the new technology in such a way as to release social synergy, has three qualifications. He is essentially a small farmer, poor and illiterate.

A technology for the poor farmer

If slogans such as the transformation of rural life, or the achievement of growth with social justice are to be translated into reality, then the new technology must be such that it can be adopted by the small, poor and illiterate farmer. Do we have such a technology? Yes, but as I explained at the beginning of this talk, its adoption particularly during the south-west monsoon season requires a certain degree of co-operative effort and a changed outlook. These in turn imply far-reaching changes in education and social organisation as prerequisites.

Let me quote a few encouraging examples of what I mean, before I close.

Here and there in our countryside, but unfortunately only rarely, we see striking examples of the economic benefit that can accrue to small cultivators by co-operative action. The Bhartiya Agro Industries Foundation at Urli Kanchan near Poona has sponsored a whole set of co-operative activities like lift irrigation, dairying, poultry and joint farming based on the concept of uplifting the rural poor through the latest agricultural and animal husbandry techniques. The work of the Kaira District Co-operative Milk Producers' Union, Anand, is too well known to need description.

first applied the concept of synergy in social sciences, says and I quote, "Societies where non-aggression is conspicuous have social orders in which the individual by the same act and at the same time serves his own advantage and that of the group...Non-aggression occurs in these societies, not because people are unselfish and put social obligations above personal desires, but because social arrangements make these two identical.

Cultures with low social synergy are those in which the social structure provides for acts which are mutually opposed and counteractive, and cultures of high synergy where it provides for acts which are mutually reinforcing...In cultures with high social synergy, institutions ensure mutual advantage from their undertakings, while in societies with low social synergy the advantage of one individual becomes a victory over another, and the majority who are not victorious must shift as they can."

According to Abraham Maslow, "The high synergy society is the one in which virtue pays...High synergy societies all have techniques for working off humiliation, and the low synergy societies uniformly do not."

To a biologist like me, there is sufficient evidence in Nature to prove that symbiosis, or the process of mutual assistance and support, is a necessary ingredient for synergy. However, it seems that the very concept of synergy has been very little used, or even understood, by social scientists in its application to man. Ruth Benedict was one of the few social scientists to apply this concept to societies, and it has been later developed by Abraham Maslow, who is, significantly enough, not considered an orthodox psychologist. A very significant definition of social synergy is the one I just quoted. From this, it appears that there is a close correlation between synergy and non-violence, a fact which should be of interest to us in the country of Mahatma Gandhi. Further, the high synergy society seems to be another name for what Gandhiji described as the Sarvodaya society. It is also evident that our society as at present organized is a low synergy society. What steps can we take to ensure that we move from this to a better state of affairs?

Individual and social goals

Individual goals have to be made to coincide with social goals. This can be done in many ways. The Communist countries have found their own approaches. Russia, China and Israel have all found their own ways of ensuring this merging of individual and social goals. Most of these methods are related to the practices of child-rearing and education. In Soviet Russia, for instance, the system of rewards and punishments in schools is such that the individual is rewarded only when the poor group succeeds. At every stage, the success and happiness of the individual is related to the success of the group in such a way that each individual

while in 1964, about 286 kilo calories of energy were needed in countries like India and Indonesia to produce one kg. of rice protein, 2,860 kilo calories of energy were needed to produce one kg. of wheat protein and over 65,000 kilo calories to produce one kg. of beef protein in the United States. Such a situation has now resulted in a widespread awareness of the simple truth that any finite resource, if exploited in an exponential manner on the assumption that the resource is infinite, will some day or the other get exhausted, thereby bringing the pattern of growth based on its consumption to ruin. It has also become clear that the tools of modernisation of agriculture, like pesticide, fertilizer, farm power and water, if indiscriminately used and excessively, based on non-renewable resources, will end in crises, now referred to as 'ecological crises,' "energy crises" and so on. For example, 96 per cent of the energy input in the United States in 1970 came from oil, gas and coal, while in the same year non-commercial fuels like dung, firewood and wastes provided 52 per cent of our energy needs. The reserves of the fossil fuels are expected to decline rapidly in the next 30 years and even now, we have started witnessing some shortages of the most desirable fuels. Our agricultural production process is still predominantly based on the use of reneweable resources but our current productivity is very low. Hence, there is urgent need for the development of technologies where the productivity of land can be continuously increased with diminishing dependence on non-renewable components of energy, by deploying recycling processes more and more effectively. A consequence of the agriculture of the high-energy-consumption and low-labour-input pattern is the diversion of labour from agriculture to more industrial pursuits and a close linkage between farm and factory. Diversification of labour use, leading to a reduction in the number of people employed in the physical operations of farming, has historically been associated with a rise in the standard of living.

Contrasting food chains

A biological consequence of affluence has been a rise in the consumption of animal products. The poor and rich nations are hence characterised today by the former depending largely on the plant-to-man food chain and the latter, on the plant-animal-man food chain. Consequently, the average per capita consumption of grain is about one tonne per year in the developed nations, out of which only about 70 kg. are consumed directly in the form of bread, biscuits, cakes and other products made from flour. The remaining 930 kg. are used to feed animals whose products like meat, milk and eggs are consumed by man. In contrast, the per capita consumption of grain per year in the developing countries is about 190 kg., most of which is directly consumed.

To summarise, the two major contrasting systems of agriculture we see today differ in the size of farm, the proportion of work force employed in agriculture, the types of linkages developed between farm and factory, the extent of consumption of non-renewable resources of energy, management efficiency, per capita productivity and income and the extent of use of animal products in daily diet. Our need is an agricultural system where the benefits of a large human and animal population, robust soils, abundant sunlight, rich ecological diversity, availability of large quantities of organic wastes and a fairly extensive irrigation network are optimised in a manner that productivity is continuously increased without damage to the long term production potential of the soil, stability is imparted to the production as well as prices of foodgrains and labour and land use diversified, so as to increase real income and purchasing power. The mode of achieving these goals was summed up beautifully by our President Shri V.V. Giri when he called upon us to make "Every acre a pasture and every home a factory".

About 10 years ago, some foreign experts believed that India could never become self-sufficient in its food requirements. They predicted the outbreak of widespread famine and hunger in India on the basis of theoretical calculations of the year when the food needs of the poor nations would exceed the capacity of the rich nations to meet them. Paul and William Paddock, for example, fixed this year as 1975. Some others felt that such a contingency would arise only in 1985. Our failure to achieve during the nineteen fifties and early sixties the anticipated results with the Community Development and the Intensive Agricultural District Programmes fanned the sentiments of the pessimists. It was widely believed that in our rural areas developmental action and achievement were being impeded by the limited sights of our farming community. Experts wondered why we should find it so difficult to become self-reliant in our food needs, when there appeared to exist several easy pathways of attaining this goal. An expert on rodent control would thus advocate the control of rats to wipe out the deficit in our food budget, while the agronomist would plead for using good seeds and some fertilizer for achieving the same end. The fact remained, however, that progress in improving production was slow and largely took place through an increase in the cropped and irrigated area, rather than through any appreciable increase in productivity. The economic plight of the small farmer remained unchanged since his real income would rise only if productivity was improved and marketing organized so that the small producer got a fair share of the price paid by the consumer for a commodity. While Government was anxious to push up agricultural production and Jawaharlal Nehru gave expression to this desire by his oft-quoted statement "Everything else can wait but not agriculture", there was despair

Indian Council of Agricultural Research is proposing to set up a number of Krishi Vigyan Kendras to impart technical literacy to practising farmers, fishermen and others. These Kendras would select in each area such means of economic growth which are most likely to give major benefits to the poorest sections of the community. In other words, those who are setting up a Krishi Vigyan Kendra will first have to make a survey of the agricultural potential of an area and then identify those aspects of growth which could help to improve the purchasing power of the poor. For example, in an exercise done in the Union Territories of Pondicherry and Karaikal, where Krishi Vigyan Kendra has been approved for establishment, it was found that the following areas needed immediate attention, if the poor are to be benefited:

(1) Improving the income and reducing the under-employment of over 10,000 fishermen.

(2) Improving the average per hectare rice yield to about 2,000 kg. as soon as possible from the existing 1,400 kg.

(3) Introducing a scientific animal husbandry programme in order to produce more milk both for marketing in Madras city and for making milk powder.

A similar Krishi Vigyan Kendra in Punjab may deal with topics like tubewell technology, repair of implements and tractors and scientific multiple cropping.

Having analysed the most effective methods of improving the income of the poorest sections of the community, and identified the major thrusts, the Krishi Vigyan Kendra has to provide training which will help the trainees to initiate change in their respective occupations. For example, in the case of the Pondicherry fishermen the training will be in the area of coastal aquaculture, which will help them to undertake fish culture in coastal estuaries, in addition to improving the techniques of fish capture. Similarly, the animal husbandry programme will impart skills in genetic upgrading, cultivation of nutritious grasses and legumes as well as the use of wastes enriched with urea as feed, health care through sanitation and immunisation and better processing and marketing techniques.

Even if we are able to provide the educational infrastructure needed for agricultural reconstruction, we would still have to develop a social organisation which can help small farmers to overcome the limitations arising from the small size of farm holdings, lack of capacity to purchase the requisite inputs and inability to get a fair price for the produce. To achieve this aim we will have to devise strategies to generate social synergy.

Social synergy

What is social synergy? Ruth Benedict, the anthropologist who would help to generate a greater sense of self-confidence and self-reliance on the part of the student. One approach to achieving this aim may lie in making an in-built provision in each one of our developmental projects for students' participation.

Student work should not be regarded merely either as social service or training but must become a distinctive and advantageous part of the project. If this approach is accepted by the Project authorities, students can become a source of great strength and dynamism to the Project, if they are properly trained and deployed.

What I have in mind is that every university student must be employed in an appropriate Plan Project for a period of two months every year, while he or she is in the University. A semester system of course-curriculum organisation would help in the implementation of this idea, although this is not absolutely essential. The summer vacation can be restricted to one month, so that the formal teaching programmes do not suffer. The assignment of students to various projects will need proper planning and adequate consultation between the universities and Project authorities. Needless to say, the assignment of students will be based on the principle of learning through work and would hence involve a planned matching of the field of study with the field of work. Thus, students of History and Archaeology may work for the India Tourism Development Corporation, of Zoology and Medicine in the family planning and preventive medicine programmes, of Agriculture, Botany. Chemistry, Physics, Economics, Engineering and Home Economics in agricultural development and child nutrition programmes and of nearly all fields in pre-primary, primary and secondary education programmes.

All scientific institutions in the country run by Central and State Governments can provide opportunities for students to work in specific projects and can at the same time give a great fillip to the cottage industry movement by supplying detailed manufacturing drawings of new implements, machinery and processes. With these drawings, university students in engineering may be in a position to help village communities in starting small-scale industries, since rural credit is becoming more easily available now.

Technical literacy for farmers

The majority of our peasants are illiterate. Unfortunately, the proportion of illiteracy seems to be higher in areas such as the arid and semi-arid regions, where the scientific transformation of the rural economy requires a much greater understanding of the principles of economic ecology. Therefore, it is obvious that unless we seriously start programmes to impart the latest technical skills to illiterate peasantry by the method of learning by doing, we will not be able to accomplish our goals. The

during the drought years of the mid-sixties concerning our agricultural destiny.

Famines and scarcities

Historically, famines and scarcities have been known in our country from the earliest times. They are mentioned in Mahabharat and there is a Jain legend of a 12-year famine in the fourth century A.D. It is recorded by the official historian in the Badshah-Namah that in the famine of 1630-32, the Emperor Shah Jehan opened soup kitchens, gave a lac and a half to charity and remitted one-eleventh of the land revenue in the affected area. Subsequently, there have been numerous famines but it was only during the famine of 1868-69, that it was clearly stated that "the object of Government was to save every life." The birth of agricultural departments in our States and of Famine Codes took place as a result of the recommendations of the Famine Commission of 1878. The Scarcity Manuals currently used by several State Governments are largely based on the Famine Codes of the last century. B.G. Verghese's penetrating articles entitled *Beyond the Famine* and *A Blessing Code Named Famine* on the droughts of Bihar and Maharashtra have highlighted the advantages conferred on the helpless rural population by famines, since it is only during such crises that at least some food and employment are assured to those living in absolute poverty.

Meanwhile a silent revolution has been taking place in the minds of our farming community as a result of the new production technologies introduced through the High-Yielding Varieties Programmes, Intensive Cotton District Programme including hybrid cotton which was introduced into commercial cultivation for the first time in the world and the Cattle Cross-breeding projects. Obsession with destructive criticism has blinded us to the meaning and implications of the increase in wheat production from a little over 12 million tonnes to over 27 million tonnes in just six crop seasons beginning from 1967-68. There has not been much interest in studying how a small Government programme in wheat was converted into a mass movement by our farmers. It is not only in the Punjab or Haryana that wheat production went up dramatically but also in non-traditional wheat areas like West Bengal. While in the past it was difficult to induce farmers to take to a rat control operation, farmers took pains, in the wheat belt, to see that rats did not migrate from sugarcane fields to wheat. While in the past everyone knew that farmers were sitting over a large underground water resource in the Indo-Gangetic plains, it was only the introduction of high-yielding varieties of wheat and rice that provided the necessary motivation for them to take to the construction of tube wells—whether made of metal or of bamboo—on a large scale. The truth of the saying "Necessity is the mother of invention" was proved to be true in the case of wheat cultivation, where farmers somehow managed to produce or get the seeds they needed, use diesel pumps if electricity was not available and get the requisite number of threshers and other implements as well as storage bins fabricated in record time. That our farmers may not wait for research workers to produce perfect tools but will themselves innovate and find a solution to a pressing need was shown by the Bihar farmer, Shri Ram Prasad Chaudhary Jaiswal of the village Lalpur who first put up a bamboo tube well in the Saharsa district. Farmers who learnt the economic value of good management in wheat also took to better practices in rice, potato and other crops, with the result that agriculture as a whole started moving forward in such areas. The sudden and steep spurt in fertilizer demand is an eloquent testimony to the credibility of the new varieties and techniques. The concept that agricultural advance in India would suffer due to the limited vision of the farming community was thus disproved. The social tensions between those who had access to the inputs needed for adopting the new technology and those who did not have similar access, only underlined the fact that those who have not derived economic benefit from such technology are equally anxious to take to the technology. The desire to change farming methods thus fanned both joy and sorrow in our countryside. This in turn generated considerable thinking and action on the part of Government, resulting in programmes for marginal and small farmers, expansion of credit facilities and more recently in integrated farmers' service societies on the lines recommended by the National Commission on Agriculture.

Assets and liabilities

Thus, starting from the mid-sixties we have gone through waves of pessimism and optimism. We have been happy over good seasons and more than alarmed by bad ones. Soon we will be a nation of 600 million and it is probably time that we look at our agricultural assets and liabilities critically and scientifically and evolve a pattern of growth which would help us to take full advantage of good seasons, be prepared for the worst and make agricultural growth yield more income and more jobs in addition to more food. This is an appropriate time to undertake such a review since, thanks to one of the best *kharif* harvests we have had so far, we can afford to stop concentrating on holding operations and divert our attention to constructive programmes. Complacency at this stage and any relaxation of relentless efforts to achieve agricultural advance would be disastrous.

I would like to deal with our agricultural assets first.

ASSETS

Sunlight, soil, water, plants, animals and human beings constitute

responsibility, to assume that they can take it and to let them sweat and struggle with it. Let them work it out themselves, rather than over-protecting them, indulging them or doing things for them".

It is time that we use this as a basic principle in education.

Yet another useful form of work experience would be the school project. Apart from the practical and economic value of the school farm, garden or dairy, it would teach another vitally necessary attitude which I have already spoken about. This is the necessity for co-operative endeavour. Even if each student had his own plot, or animal, or pond, he would, in the course of work, learn without being asked to combine with his fellow students for certain operations, the need for certain activities to be undertaken by all at the same time, the economics of sharing and so forth. In this way, co-operative endeavour would become a necessity for the individual, for the success of each individual's project would be inevitably linked to the performance of these joint operations at the right time and in the right way.

Involving university students

At the university stage, fewer people are involved, but they need to be involved differently. Let me begin by quoting some facts. In 1969-70, about 3 million students were enrolled in higher education, about 2½ million men and ½ million women. Of this, only 1.6% of the men and 0.4% of the women were engaged in any kind of agricultural studies. Only 176 women were enrolled in agricultural universities. In a country with 80% of the population engaged in agricultural pursuits and living in the rural areas, it is sad that such a small fraction of men and women are engaged in studies which can contribute to rural development or agricultural productivity. It is specially sad that though women contribute equally to the labour force in agriculture, performing many of the key operations and the most of the more tiresome ones, agriculture as a profession is not regarded as a suitable one for women at the higher stages of education. This reflects the gap between the educated classes, who are mostly drawn from the urban areas, and now-a-days also from the rural elites, and the rest of the population. Apart from providing more opportunities for higher education and technical studies in agriculture, we have also to think of other practical ways in which the great majority of university students can be helped to become involved in the work of rural development and to acquire some understanding and sympathy for the problems of the greater part of this country's population. An example of how non-agricultural colleges can participate is the good farm run by the staff and students of the Madras Christian College, in what was until 1965 a scrub jungle.

Making work-experience an integral part of university education found the experience very rewarding to staff and students alike. Why not bring in more and more part-time teachers, people who have skills and knowledge in agriculture and related crafts or at least send students out to them. Some experiments along these lines are being carried out. For instance, in Bombay, at the city level, the Bombay Municipal Corporation has arranged for students from a number of schools to be placed for regular work in industrial establishments for two days a week. This gives the students real work experience, preliminary training for their future careers, and helps them to find placements after school. Here the same idea has been applied in a different sphere, the industrial one. In some districts of Maharashtra, secondary school students are being placed in villages in batches, residing with farm families, for several weeks at a time, under the supervision of their own teacher. The objective here is to enable non-farm students to learn more about agriculture and farm operations through direct participation and observation. The students live with the farm families, and join in their daily work and routine. The difficulty has been that the teachers are often ill-equipped to guide the students with the information that they need. Such schemes are steps in the right direction. They need to be expanded and adapted to a wider variety of experiences and students.

Work projects for students

Another useful adaptation of the idea of work experience is to give academic recognition, through marks, to real economic work projects, self-chosen by students and carried out by them in their spare time, either alone, or with the help of their families. A boy or girl, who can run a simple project such as a poultry unit or a kitchen garden, would have learnt much by way of independence, responsibility and initiative, as well by way of arithmetic, science and economics. It is needless to add that the conventional literacy skills of reading, writing, and arithmetic will also be fully utilised in such projects. Of course, it means more time and effort on the part of teachers and administrators to identify and initiate such projects. Further, it requires the technical assistance of officials of agriculture departments and extension agencies. It is naturally much easier to provide artificial work in the class room and call it work experience than to help children to engage in real work and to assess it as it deserves. Children become responsible when they are obliged to carry responsibility. The majority of children in our country are already working and carrying responsibility. It is up to us to devise an education that will encourage and support them in their efforts by providing a place for such tasks. Here I would like to quote A.H. Maslow, the humanistic psychologist, speaking on the development of responsibility:

"It looks as if one way to breed grown-up people is to give them

the basic resources of our agriculture. Fortunately, sunlight is abundant except during limited periods in the monsoon season and generally does not constitute a limiting factor in production. In arid and semi-arid areas, the intensity of solar energy is fairly high and exceeds 650 cal/cm^2/day. Under such conditions evapo-transpiration rates become high. The average annual values of energies available in peninsular and north India are 473 and 460 cal/cm^2/day respectively. Apart from the use of sunlight by plants in the process of photosynthesis, solar energy is used in rural areas for purposes like drying of crops and grains, distillation, evaporation for salt production and heating. There is however, considerable scope for improving the use of sunlight both by plants, through multiple cropping, and by converting solar energy into thermal energy.

Out of our total geographical area of 328.05 million hectares, the net area sown during 1969-70 was about 139 million hectares. Forests occupied about 65 million hectares and uncultivated land was about 101 million hectares. Thus, the net sown area under crops in 1969-70 was 45.5% of the reporting area and the area under forests was 21.3%. The net national product was Rs. 34,253 crores during 1970-71 at current prices and Rs. 18,876 crores at constant 1960-61 prices. At 1960-61 prices, the contribution of agriculture, forestry and fishing to net national product in 1970-71 was 44.4%. The contribution of agricultural products to the total export earning in the same year was 37.1%.

Diversity in physiography

The physiography of our country shows great diversity. On the one hand, we have major mountain ranges with the Himalayas, at once one of the youngest as well as the mightiest of the world's mountain systems, in the north and the Aravallis, the Vindhyas, the Satpuras, the Eastern and Western Ghats and the North eastern ranges including the Garo, Khasi and Jaintia hills in the other parts of the country. Plateaus, ranging in elevation from 300 to 900 metres, constitute a prominent feature of our topography, the well-known among them being the Malwa, the Vindhya, the Chhota-Nagpur, the Satpura, the Deccan, Ladakh and Meghalaya. A very large part of the country consists of extensive plains watered by great rivers where a considerable proportion of humanity live. In the rivers originating from the Himalayas, the dry weather flow is generally good due to water coming from melting snows and glaciers. The lean period for these rivers is the winter months but at no time is the flow so reduced as in the peninsular rivers. The flow in the rivers of peninsular India undulates heavily, with big discharges during the monsoons followed by low discharges during the rainless months. Variations of the order of 1 to 300 in the mean monthly flows of these rivers are common.

Our climate shows equally great diversity, ranging from continental to oceanic, from extremes of heat to extremes of cold, from extreme aridity and negligible rainfall to excessive humidity and torrential rainfall. The Himalayas present a barrier to the influence of cold winds from Central Asia and give the sub-continent the elements of a tropical type of climate. The variations in rainfall, temperature and humidity caused by the incursion of comparatively cool currents from the Indian Ocean across the Bay of Bengal and the Arabian Sea and by the movement of shallow depressions, which originate outside India, to the west, lead to extremely complex weather patterns, which prevail even over those areas which can be grouped climatologically under a single type. Thus, temperature, rainfall and the amount of vapour in the air, which influence greatly the growth of crops, show wide variation even within small areas.

An interesting feature of wind system over the Indian Ocean and the adjoining sea and land areas is the seasonal reversal of the monsoon. During the late summer, the winds flow from the south-west over the sea towards India and Burma, while during the winter, the flow of currents is from India and Burma over the Bay of Bengal and the Arabian sea towards the Equator. The south-west monsoon season is responsible for over 80 per cent of the total rainfall in most parts of the country.

On an average, we receive an annual rainfall of about 370 million hectare metres. It has been estimated that about 80 million hectare metres seep into the soil of which about 43 million hectare metres remain in the top layers and contribute to soil moisture which supports crop growth. The ground water recharge available for utilisation may be of the order of 26.75 million hectare-metres, while the current utilisation is about 10 million hectare metres. As a result of the various major, medium and minor irrigation projects undertaken, the area under irrigation during 1969-70 was 30.3 million hectare. The Second Irrigation Commision has calculated that the ultimate potential for irrigation from conventional sources is 81.7 million hectares. It is premature to guess what the contribution of weather modification and desalination will be in the future to augment water availability in drought-prone areas. The States which have less than 15% of the net cultivated area with irrigation facilities are Mysore, Madhya Pradesh, Maharashtra, Gujarat and Rajasthan. Much of the knowledge we have on ground water resources is confined to the alluvial and semi-consolidated areas, whereas 70 per cent of the total geographical area of the country is covered by hard rock. The geo-hydrological studies carried out by the Geological Survey of India as well as the studies carried out under the auspices of the Central Ground Water Board have revealed great opportunities for scientific ground water exploitation. Fresh ground water has been found in the heart of the great Indian desert near Jaisalmer, in the Narmada and Purna Valleys, the

Banks can finance entire production programmes, as for example the production of a lakh of tonnes of sunflower oil or the production of a certain quantity of soybean in a suitable area, and thereby assure the credit and other infrastructure for the entire production chain and not merely for components of the chain. Similarly, pesticides firms can sponsor programmes designed to ensure pest-proofing of important crops in the poorest villages in their area of operation. All such projects will provide excellent educational opportunities for the students of the area, besides serving as demonstrations of new techniques.

Work experience at the upper primary and secondary level too can be effective if carried out in a different manner. This idea of introducing work experience into schools seems rather artificial and unnecessary in our context. At an optimistic estimate, about 70% of the children aged 6-11 are enrolled in primary schools. If we consider children upto the age of 14, and take account of wastage and stagnation in education, then the number of children between 6-14 who are not in school may be as large or larger than the number of children in school. Most of these children are already working, not indeed to gain work experience, though they are gaining it no doubt, but out of sheer economic necessity. In these circumstances, bringing work experience into schools seems redundant. Would it not be more meaningful to carry educative experience out to the work, where the children already are anyway? This means much more than open-air classrooms, or discussing arithmetic in terms of bags of manure or hectares sown or other agricultural operations. Of course, such activities are necessary and important. But it would mean much more. It would imply a profound change in the school programme, introducing such activities as allowing children to work in their own or others' farms for part or most of the day, planning for learning-oriented and not teaching-oriented education, and getting new kinds of teachers to deal with the new tasks.

Who is to teach work experience as conceived in this way? The traditional school teacher, who is mostly drawn from the white-collar class and has little practical experience of agriculture may not always be the most suited to this task. In fact, it has already been observed in areas where the new technology has spread, that the technical knowledge of rural parents, who may be progressive farmers, is far ahead of the outdated agriculture taught in the schools, even by qualified teachers. Why not allow such parents, or other local farmers, to teach part-time? Often even the children of farm families know more about the latest developments in agriculture than the non-agriculturist school teacher. Even at the post-graduate level of education, the Indian Agricultural Research Institute, New Delhi, which started a few years ago the practice of inviting farmers with practical wisdom for brief periods as Visiting Professors, nature to develop scientific skills, aptitudes and habits of thought. How often are children in *balwadis* and primary schools forced to remain within the limiting walls of a barren and bare classroom, because of the false impression that education is something that must take place within a building? How few children in *balwadis* are taken for walks and helped to learn about nature? On the other hand, there are commendable efforts in some places to use nature itself as a medium of education, as in the Meadow School of the late Tarabai Modak, which carried education to shepherd boys right in the meadows where they were grazing cattle. Rabindranath Tagore was an ardent advocate of this approach. There have been other similar ventures, but all have remained small, local and isolated. At a different level, the Avinashilingam College of Home Science in Coimbatore for instance, has compiled a set of songs for preschool children incorporating knowledge about nutrition. The ICAR and the Extension Directorate of the Union Ministry of Agriculture are shortly bringing out a publication which will be a collection of games for use in classrooms and in recreation introducing information and concepts about agriculture. They can be played both by other adults and by children. The details of the games will, however, have to be developed in each Block using data applicable to that region. We need many more such educational games and kits that will make use of the play way idea of teaching science in general, and agriculture in particular.

The traditional media of entertainment as well as the mass media of radio, cinema and television can also be harnessed to the cause. Even now many of the new crop varieties are known in villages at some places as "Radio varieties", since information on the new strains reached the illiterate cultivators through the radio. It is a happy sign that newspapers are increasingly assigning more space to items relating to agriculture and rural development. While the English newspapers play an important role in conveying messages to the policy maker, the language press, besides the radio and cinema, forms the most significant medium of conveying information to villagers. Several of our leading newspapers have now whole time agricultural correspondents and experts specialising in agricultural themes. Developmental journalism took to a new path when an integrated village transformation project was initiated in the Chattera village of Haryana State by *The Hindustan Times*. Apart from its contribution to human happiness and welfare, this project is becoming one of the best documented accounts of rural change.

Role of banks and companies

Both banks and public and private sector companies can play a great role in combining their regular work with the art of communication.

Rajamundry and Tirupati sand-stone areas of Andhra Pradesh and the Cuddalore sand stone and the Neyveli lignite areas of Tamil Nadu, in addition to the already well known areas of Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal and Assam. Opportunities for lift irrigation from perennial streams and rivulets are also yet to be fully utilized.

With the growth of vegetation and evolution of agriculture, what were once geological deposits got gradually converted into soils. The topography, biology, physics and chemistry of soils provide an interesting account of past history of that soil. In particular, they indicate the extent of interest taken by man in the care and maintenance of soil fertility and productivity. Examined by such criteria, our record is dismal.

Our major soil groups

We have four major groups of soils-alluvial, black, red and laterite, several other types like forest, desert, alkaline, saline and acidic soils occuring in smaller areas. The red soils occupy 72 million hectares and are found in both high and low rainfall areas. The stored moisture of a saturated red soil profile is generally sufficient to support a standing crop only for 2 to 4 weeks. Hence mostly *kharif* crops are raised in such soils. Red soils are generally low in nitrogen, low to medium in phosphorus, and medium to high in potash. Drainage is not usually a problem in such soils and hence they can be converted into irrigated land without difficulty, if a water source is available.

Black soils which occur in about 64 million hectares are variable in depth and are generally found in regions with an annual rainfall ranging from 500 to 1200 mm. While in the shallow black soils, only *kharif* crops are grown, *rabi* crops are raised in the deeper soils with residual moisture. Drainage and erosion are serious problems in such soils and hence there have to be appropriate arrangements for drainage and soil conservation, when such soils are brought under irrigation. Black soils contain 40 to 60 per cent clay and are plastic and sticky when wet and very hard when dry. They contain a high proportion of calcium and organic matter, magnesium carbonate, considerable iron and fairly large quantities of magnesia, alumina and potash. In black soils derived from ferruginous schists, there is generally a layer rich in nodules of 'kankar' formed by segregation of calcium carbonate at lower depths. The most important difference between the red and the black soil lies in the amount and type of clay mineral present. The montmorillinitic type of clay predominates in the black soil and this imparts the characteristic swelling and shrinking properties of these soils. On the other hand, the non-swelling kaolinitic clay predominates in the red soil. The black soils, also known as 'grumosol', 'regur' and 'black cotton soils', have self-mulching properties, the repeated wetting and drying causing clods to crumble into small aggregates forming a surface mulch. These soils are also referred to as being 'self-swallowing', since the surface mulch falls into the deep cracks and thus becomes incorporated into the sub-soil. Thus, on the one hand the black soils have a good capacity for conserving soil moisture, and on the other, they need proper tillage and management to overcome the handicaps of their bad structure.

Alluvial soils occupy an area of about 64 million hectares and are generally deep and variable in structure, ranging from drift sand to loams and from fine silts to stiff clays. The main characteristics of these soils are derived from their having been deposited as silt by the rivers, particularly those of the Indo-Gangetic and the Brahmputra systems. The physical characteristics and nutrients status of these soils vary considerably. In the south, for example, the Godavari alluvium is rich in lime, phosphates and potash, while the Cauvery alluvium is relatively poor in plant nutrients. In Assam, the old alluvial soils are acidic, while the new alluvium is usually neutral or alkaline. In West Bengal, the old alluvial areas are much less fertile and productive than the new alluvial soils.

Hard pans occur in the soil profile, particularly in the Indo-Gangetic alluvium of Uttar Pradesh, Punjab, and Delhi as a result of infiltration of silica or calcareous matter and the presence of 'kankar'. Such hard layers impede root growth and percolation of water. In general, alluvial soils are ideal for irrigation and ground water exploitation.

In about 13 million hectares, we have laterite soils, generally associated with undulating topography in regions with annual rainfall ranging from 1200 to 3000 mm. They are essentially composed of a mixture of the hydrated oxides of aluminium and iron with small quantities of manganese oxide and titania. These soils are poor in lime and magnesium and deficient in nitrogen. Generally, they are poor in available phosphorus and calcium and have a relatively low organic matter content. Such soils are well-developed on the hills of the Deccan, Mysore, Kerala, Tamil Nadu, Mydhya Pradesh, Eastern Ghat region, Orissa, Maharashtra and parts of Assam. The high and low level laterites of Tamil Nadu and Kerala are rich in plant nutrients, supporting paddy in the low levels and tea, coffee, rubber and cinchona at the higher levels. The higher the altitude, the more acidic is the soil. There is a good potential for exploiting ground water in many lateritic areas.

In addition to these major groups of soils, we have problem soils suffering from salinity and alkalinity in about 7 million hectares. There are also peaty saline soils called 'kari' soils which are heavy black soils, highly acidic and rich in organic matter. Marshy soils occur in the coastal tracts of Orissa, the Sunderbans and other areas of West Bengal, north Bihar, the Almora district of Uttar Pradesh and the South-east

referred to the possibilities for making full use of the 3-dimensional space, and the availability of different kinds of fish food in a pond, through stocking different kinds of fish which can derive their food from the bottom, and upper and middle levels. Similarly, there are opportunities for adopting new techniques in areas like the production of quality fish seed through induced breeding, the cultivation of air-breathing fish in the swampy areas and the culture of frogs for export. In marine fisheries also, culture techniques can be introduced to supplement the income from capture fisheries. Mussel culture, growing milk fish, mullets and certain species of prawns in coastal lagoons containing salt water and pearl culture can all improve the economy of the fishermen in our coastal areas.

To sustain high levels of biological productivity, we also need to generate a general awareness in the entire community of the crucial significance of conserving soil, water, flora and fauna. Like game and wild life sanctuaries, we need to develop "Crop Gene Sanctuaries" in those parts of our country where valuable genes are found in the primitive cultivars and native flora. Such a step can help to prevent the erosion of valuable genes. In contrast to soil erosion, gene erosion is not visible to the naked eye and hence does not attract attention.

Changes in educational outlook

Having spoken about the extension needs of the new technology, I would like to turn to the social and educational infrastructure which is a prerequisite for the successful adoption of the technology. I shall deal first with the educational aspect.

What kind of education do we need that would be relevant to our society, dependent as it is on agriculture as its major activity ? And what practical steps can we take to change our educational system into such a one ?

The changes required are of two kinds : at one end, we need to bring about a change in outlook, creating an awareness of biological surroundings, and a consciousness of the possibilities of synergy. This can be done only when there is an inundation, so to speak, at every level of education, of materials that will create such a consciousness. At the other end, we need to give technical skills to illiterate and semi-literate adults, which will enable them to understand and use efficiently the new technological package. Between these two, there are a wide range of activities which can be applied at every educational level.

During the early years of childhood, before the child begins to receive formal education, and in primary school, the major emphasis should be on living in nature and with nature, learning about nature through direct observation, and using the materials provided in be the poor cultivator's response to a high-risk farming situation, unless he has protection by means such as crop insurance. This is an important reason for the relative stagnation of *kharif* crop production in our country, where in spite of moisture availability, the farmer hesitates to invest on inputs in areas which are prone to pests and diseases, water-logging and operational problems in land preparation.

Co-operative effort is not only needed in the delta areas during the *kharif* season but even more importantly, in the dry farming regions. While an individual farmer can increase the storage of moisture in the soil profile of his own field through tillage, mulching and other measures, the possibilities for collecting all the run-off water and using it for a crop life-saving irrigation later, can be realised only if there is group action in accordance with the topo-sequence of the farms.

Changes in cultural practices

We also find that several basic changes in cultural practices may be needed to get the best out of the new crop varieties. For example, in dwarf wheats, sowing has to be shallow, first irrigation has to be given at the time of initiation of crown roots and population density should be higher. In rice, traditional practices such as low seed rate under direct seeding, wide spacing, deep planting and bunch planting under transplanted conditions and drying the field to promote the establishment of seedlings are all intended to retard luxuriant vegetative growth in the earlier tall varieties, which have a proneness for both excessive vegetative growth and lodging or falling down. In contrast, the new dwarf rice varieties need almost the opposite kind of treatment, if they are to reveal their full genetic potential for the yield.

It is obvious that to accomplish all these tasks successfully we need to develop educational and organisational procedure which would, on the one hand, make the literate better equipped to discharge the functions of gram sevak, gram sevika, credit agent, teacher and other agents of change, and on the other, make the illiterate highly skilled and efficient partners in adopting the latest scientific advances. I do not propose to reiterate other obvious requirements like the timeliness of credit and input supply and appropriate pricing and marketing arrangements. I would, however; like to stress that in addition to the procedures currently in operation for product pricing, we should also pay serious attention to evolving long-term pricing policies for factors of production, such as fertilizer, pumps, pesticides and others. Product pricing alone without attention to the pricing of means of production will tend to result in controversies and problems.

It is not only in agriculture and dairying that new techniques need to be popularised but also in inland and marine fisheries. I have already

coast of Tamil Nadu. Forest soils containing a heavy deposition of organic matter derived from forest growth and desert soils occuring in parts of Rajasthan, Gujarat and Haryana, constitute the other important groups.

The main rivers of the Indo-Gangetic plains have extensive areas lying adjacent to them known as *khadir* in Western and Central Uttar Pradesh, *diara* in Bihar and eastern U.P. and *char* in West Bengal. The soils of these areas range from unconsolidated sand to silt and are rich in potash but low in phosphorus. Different management procedures are needed for the sandy, water-logged, saline and good areas of the riverine soils of Bihar, Uttar Pradesh and West Bengal. In U.P. and Bihar alone, such area extends to about 2.4 million hectares and these are potentially high production soils.

We have also rich rock phosphate deposits both in north and south India and phosphorus rich sands on the beaches of Laccadive, Minicoy and related group of islands in the Arabian Sea. Gypsum deposits are available in Rajasthan.

Floristic diversity

Consequent on our varied soil and climatic endowments, we have over 20,000 plant species occurring in our country, a number which is far higher than those found in countries with a larger land mass. Such a floristic diversity is obviously the consequence of the prevalence of tropical, sub-tropical, temperate and alpine areas, where the precise flora may vary depending on latitude, altitude, variation in mean annual day and night temperature and the severity of summer and winter. We have over 4,000 woody species of plants and among them about 50 are of major utility. The potential productivity of our forests has been estimated to be of the order of 490 million cubic metre of wood. The current annual harvests comprising 12.9 million cubic metre of fuel wood and 8.9 million cubic metre of industrial wood are, however, extremely low, the gross revenue being only Rs. 21.50 per hectare.

Our wild plant wealth, used in various forms by people in tribal areas, includes about 500 species, mainly belonging to the families Gramineae, Orchidaceas, Papilionaceae, Rubiaceae, Euphorbiaceae, Moraceae, Compositae and Labiatae. If we total up plants under cultivation on some scale, their number comes to about 250, excluding the ornamental trees, shrubs and herbs. It is believed that about 35 of these species might have been first domesticated in India and our neighbouring countries. There is a large genetic variability in our country in crops like rice, sugarcane, mustard, *arboreum* or Asiatic Cotton, *tossa* jute, various pulses, vegetables such as brinjal, cucumber, gourd, yam, black pepper, cinnamon, turmeric, mango, banana, citrus, jack fruit, *ber*, *phalsa*, *amla*, and *jamun*. Even in plants introduced from the New World, considerable variability appears to have been generated subsequent to their arrival in India. A few examples are maize, chilli, potato and cucurbits. We have areas in the country like the North Eastern Himalayas which have very rich variability in crops like rice, maize and *Citrus*. A unique type of *arboreum* cotton with long bolls occurs in the Garo hills. There are trees of mandarin oranges in the Jowai area of Meghalaya which have been productive for over a century. The Jeypore tract of Orissa is also a centre of considerable variability in rice, while in central India, there is vast variability in several pulse crops. It is only recently that serious attempts have been made to domesticate some of the medicinal plants which are otherwise directly collected from the wild state and used.

An example of such a recent domestication is the release for cultivation in the Bangalore area of strains of *Dioscorea floribunda*, a plant native to Central America and which contains Diosgenin, a steroid used in oral contraceptive pills.

Impressive animal wealth

Equally impressive is our animal wealth. According to the livestock census of 1966, our total livestock population was 344 million including 176.0 million cattle and 53 million buffaloes. Both in cows and buffaloes, we have an impressive array of hardy and productive breeds. Exotic breeds like Holstein, Brown Swiss and Jersey are being increasingly used in cattle breeding programmes. More than 60 per cent of the total milk production comes from about 23.1 million buffalo cows. The best dairy animals in our country have, however, an average production efficiency of only 25% of their counterparts in Europe and North America.

We have about 4.2 per cent of the world sheep population, numbering according to the 1966 census about 42.0 million. In addition to wool, mutton and milk, sheep contribute at present 15.5 million pieces of skins and 2.1 million tonnes of manure. Sheep abound in semi-arid and arid areas and both the hot desert of Rajasthan and the cold desert of Ladakh offer great scope for sheep and goat improvement. Our poultry population is equally high, having been estimated at 115 million in 1966.

Animals also contribute over 28 million H.P. of energy per day for agricultural operations. Good animals found in states like Punjab, Haryana, Andhra Pradesh and Tamil Nadu may give about 1 H.P. per pair per day of 8 hours, while those in the eastern states may give only half as much. It has been calculated that to produce an yield of 2 tonnes per hectare, the average power requirement would be about 0.75 H.P. per day. The current power availability including those provided by man, animals, tractors and power tillers comes to only 0.30 H.P. per hectare. Thus, inadequacy of power is one of the basic causes for our

during April-May. These tasks can be easily accomplished by even village school boys and girls. If such early steps are taken, the small population of *Pyrilla* that may still remain is likely to be attacked by natural enemies during the rainy season and the problem may come under control easily. If, on the other hand, simple steps like crop sanitation, removal of eggs from the under-surface of the leaves at the appropriate time and subsequent steps like attracting the nymphs and adults of this pest by light traps, are not followed, then the pest assumes a serious dimension towards September as it did in some areas of the north India this year. Since the sugarcane plantation would be full grown at that time it would be difficult to get into the field and spray with chemicals. At that stage, the method of aerial spraying or use of power sprayers becomes the only choice left. Though inevitable, when the pest has assumed menacing proportions, it is obvious that making a habit of such a method in our country would be tantamount to bypassing our major strength, viz., our large population, and to increasing the already high cost of cultivation.

The emerging agricultural technology is of two major kinds with regard to the case of adoption. In one kind, as for example, the new technology of wheat cultivation, the economic benefits derived by a farmer by adopting the technology are not influenced by what his neighbouring farmer does or does not do. In other words, the technology is capable of successful individual adoption, in economic terms. In the other kind, the economic benefits conferred by the technology on the farmer will be proportional to the extent of co-operative action generated on the part of an entire village or water-shed community. Rice and cotton cultivation and prevention of disease epidemics in cattle are good examples. Even in the Punjab, with one of the finest farming communities in the world, the average yield of cotton is low, being only 368 kg/ha. In contrast, in the Arab Republic of Egypt where cotton cultivation is managed co-operatively without any infringement of individual ownership, the average yield is 780 kg/ha. Pest control and water management in rice are best done co-operatively in a village. In fact, if this can be accomplished, even some of the fertilizer lost through leaching in drainage water can be recycled, by collecting such water in a pond at the lowest point and re-distributing it. I have already stressed the need for achieving a doubling in fertilizer response from the present low level of about 10 kg. of grain per kg. of NPK nutrients. I also pointed out earlier that the emerging concept of pest avoidance is pest management and not just chemical control. All these aspects of the new technology would need understanding and co-operation among neighbouring small farmers. If this is not achieved, the risk element in crop production will be high. A low-cost and low-effort agriculture will not enough forethought was given to the ecological consequences of developmental projects. However, the authors of the book also admit that most of these projects were designed by experts from the developed countries, often with limited knowledge of the client countries, and based on the different and irrelevant experiences of their own countries. If such programmes were accepted by the poor nations, it was for other reasons which I need not go into here. What is needed, however, is a close and detailed understanding of local eco-systems, and its application to local situations by those who are fully informed of the parameters of the problem. If development is not to be destructive, then the developing countries must take responsibility for understanding their own ecological needs, resources and patterns and planning their development accordingly. Ecology has to be a positive force in the poor countries, one which supports the economic growth we so urgently need, and not just a conserving force. This can be achieved when the people of each area participate, through Block and District Level Land Use and Crop Planning Forums, in the formulation of detailed land and water use plans for their areas. Land use planning at the Block level, assisted by guidelines on market needs and opportunities by a suitable authority at the State level and on inter-State crop adjustments and export opportunities by a Central agency, would alone result in a dynamic agriculture, where the profits of progress accrue to all sections of the community.

Village-level co-operation

For an efficient adoption of the technology at the field level, I referred in the last lecture to the need for the development by scientists of appropriate drought, good weather and flood avoidance codes for each agro-ecological area. Such codes would be of immense benefit to the developmental administrators as well as to Village Panchayats, Zila Parishads and other agencies who have to get projects translated into field accomplishments. It is obvious that tasks like recycling of all wastes, and land use planning based on an appropriate admixture of agriculture, animal husbandry, fishery and forestry, require considerable understanding and co-operation at the village level. The only approach to rapid economic development which can succeed is to optimise the advantages of our large population, vast numbers of whom are now neither participants nor beneficiaries of development activity.

For example, let us take the case of the control of *Pyrilla*, a serious pest of sugarcane. *Pyrilla* is not only affecting sugarcane but is now becoming serious in other crops like wheat and *jowar*. The most economical and effective method of controlling this pest would be field sanitation involving the burning up of all trash after the harvest of sugarcane and the collection of eggs of the pest from the lower surface of the leaf

inability to improve the efficiency of farming through timely agricultural operations.

Marine fisheries

Fisheries, both marine and fresh water, constitute one of our great assets. Over 3 million persons live on marine fisheries and the gross annual revenue to the country from fisheries is over 300 crores of rupees. Our marine fish catch has increased from about 4 lakh tonnes in 1947 to about 1.2 million tonnes in 1971. We are now the second biggest shrimp producing country in the world and the export of seafood during 1972 earned for the country over Rs. 60 crores. The estimated potential catch from the western Indian Ocean is about 8.9 million tonnes consisting of 4.4 million tonnes of pelagic fishes and 4.5 million tonnes of demersal fishes including prawns and other crustaceans. The potential catch from the eastern Indian ocean is about 5.5 million tonnes which includes 2.4 million tonnes of pelagic fish and 3.1 million tonnes of demersal fish. Another index of the untapped marine fish resources we have is provided by comparative figures on catch in different oceans. The yield per sq. km. is about 233 kg. in the Atlantic ocean and 196 kg. in the Pacific ocean, in contrast to 37 kg. in the Indian ocean. Even out of this low yield, we catch very little. For example, the total tuna catch from the Indian Ocean is about 175,000 tonnes, out of which our share is about 5,000 tonnes. The rest is caught mainly by Japanese, Korean and Taiwanese vessels.

Though the current contribution of inland fisheries, including both capture and culture fishes is low and amounts only to about 690,000 tonnes per year, there is vast scope for improvement through modern aquaculture techniques. Water pollution and water weeds could become some of the greatest threats to fish culture and hence deserve serious attention. Domestic and municipal wastes contribute more in many areas to pollution, than industrial effluents.

Any account of our agricultural assets will be incomplete without a reference to the excellent network of agricultural universities, research institutes and demonstration-cum-training centres which we fortunately have. A recent analysis at the Yale University has shown that while investment in agricultural research has been very small in many parts of India in relation to other sectors of research, the payoff from investment on agricultural research in our country has been one of the greatest in the world. Among factors which have contributed to the effectiveness of our agricultural research system is the development by the Indian Council of Agricultural Research of a national grid of co-operative experiments conducted by scientists belonging to all the relevant disciplines and institutions. Such all-India co-ordinated research projects now number over

70 and cover all the major areas of crop, animal and fish improvement. The data collected in such projects are discussed at all-India workshops and decisions on recommendations to development agencies and farmers are made collectively by all the concerned scientists. Another important strength of our research system is the direct linkages which have been established between the research centres and the farmer through National and mini-kit demonstrations, Krishi Melas and travelling seminars. This feed back relationship assists in the fine tuning of the research apparatus to the needs of its clients. Though impressive in terms of contributions, our research efforts are still very small in relation to the magnitude and diversity of problems facing us.

I shall now turn to some of our major liabilities.

LIABILITIES

The low productivity of our agricultural systems is well-known and comparative statistics place our country in the bottom group with reference to the yield per hectare of many economic plants like rice, wheat, jowar, maize, pulses, oilseeds and cotton. An important reason for our relatively poor average agricultural productivity is the vast area under the important crops, which includes considerable marginal lands. Historically, cropping systems have evolved partially due to ecological and pest and disease compulsions but more importantly, on the basis of the home needs of the farmer and his family. We now know that many low-yield environments for rice or wheat may constitute high-yield environments for some pulse or oilseed crops. An effective food distribution machinery can pave the way for re-adjustments in crop planning based on considerations of ecology and economics. If this is not done, our agriculture will become increasingly inefficient and expensive and our cost of production will increase, since wages tend to rise with or without co-incident improvement in productivity. For example, our average rice yield now is about 1170 kg. per hectare and if the tentative Fifth Plan projection of productivity improvement is all that we can achieve, the average yield will be 1375 kg/ha by 1979. In contrast, the average yield of rice even in 1971 was over 5000 kg per hectare in the Arab Republic of Egypt, Japan, Italy, the United States and several other countries. Thus, after the inadequacy of farm power, a major handicap is defective land and water use resulting in low yields.

Probability estimates

I mentioned earlier that one of our great natural assets is variability in weather and soil conditions which fostered the domestication of a wide range of economic plants and animals. Aberrations in weather, however, also constitute a major handicap. The rainfall distribution is skewed,

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Social and Educational Requirements of New Technology

In yesterday's lecture, I described several of the current trends in the improvement of the productivity of hungry soils in a way that the short-and long-term goals of development are harmonised. I said that the emerging technology is based upon an understanding of the principles of ecology.

I must here draw a clear distinction between the different meanings which this term can have for people in different situations. In the developed world, the growing importance of the science of ecology is largely the result of the efforts of the conservation movement. It is essentially a movement to use ecology to maintain, for the already rich people of those countries, the very high standards of living which they currently enjoy. It is a protective movement, aiming to prevent further depletion of resources already severely threatened or eroded and a further degradation of the environment.

However, for the developing world, ecology has to be understood in a very different sense. Most people do not have even the bare necessities of life and therefore hardly any standard of living to conserve or to protect. Rapid economic growth is hence a prime necessity. Human wastes and civic effluents form a far greater source of pollution in the poor nations than scientific and industrial pollutants. Our Prime Minister, Shrimati Indira Gandhi, made this point vivid at the United Nations Conference of Human Environment held last year in Stockholm, when she described poverty as the greatest pollutant. In our situation, knowledge of ecology should be regarded as an instrument of balanced and rapid economic growth.

A recent publication, entitled *The Careless Technology* points out, with the help of 50 selected case studies, that a high proportion of the development efforts in the developing countries have been destructive, especially of precious natural resources and delicate but ill-understood natural balances. The book demonstrates that time and again face serious threat from synthetics, unless cotton strains can be developed which can respond well to chemical finishing treatments capable of conferring on cotton 'easy care' properties like drip-drying and crease retention. The preliminary work done so far indicates that there is scope for screening varieties for these attributes.

An exciting era

We are thus in an exciting era in agricultural and food science. Thanks to the growing involvement of more and more physicists, chemists, climatologists, mathematicians and engineers in studying and solving biological problems, we can hope for continued progress in unravelling new approaches to improving productivity. Remote sensing, satellite photography and satellite television have all great applications in soil and ground water survey, crop censussing, disease forecasting, prediction of floods and cyclones and mass communication. The National Commission on Agriculture in an interim report on Agricultural Research and Education has stressed that in our legitimate concern for results of immediate applied value, we should not dry up sources of basic research. Research in production physiology, molecular biology, cellular biochemistry, design engineering, construction of production models on the basis of a systems approach, all deserve to be supported and intensified. If some of the current experiments designed to confer the ability for biological nitrogen fixation on cereal crops, thus making them behave like legumes, meet with success during the next 10 years or so, this will be one of the greatest boons that scientists can confer on the poor cultivators. There is evidence that the current highest yields obtained in wheat and rice represent less than half of what is theoretically possible. Scientists have hence much to to do.

While the onward march of science relevant to human welfare must go on, it is our duty at every point of time to ensure that the people, for whose welfare the scientific work has been undertaken at public expense, benefit from the knowledge gathered and material developed. I shall discuss in the concluding lecture some approaches to this vital problem.

about 80% occurring during the south-west monsoon season. About 30% of our geographical area receives annually less than 75 cm. rainfall and the occurrence of drought, floods, breaks in monsoon, cyclonic storms, thunderstorms and duststorms are common in one part of the country or the other. Although the periodicity of such weather aberrations cannot be determined with precision, it is possible to work out anticipatory measures and cropping systems on the basis of probability estimates. This is yet to be done systematically.

The next major handicap is the growing loss of soil and the damage that is being done to soil health and fertility. For reasons which are not clear to me, there has been a great neglect of the soil in our country in comparison with China or Japan. While it takes anywhere between 100 to 400 years for one centimetre of top soil to be formed in nature, all this soil can be lost in just one year due to erosion. It has been estimated that nearly 80 million hectares out of the 139 million hectares under cultivation require attention from the soil conservation point of view. A wide range of factors such as denudation of forests and vegetation cover, inappropriate tillage and cropping techniques and practices like shifting cultivation, are causing a considerable loss of valuable soil through water and wind erosion.

Shifting cultivation, known as *Jhuming* in the north-eastern Himalayan region, involves cutting down all vegetation from hill slope, use of fire to clear the debris, growing a crop like a hill paddy, millets, sweet potato or beans, abandoning the land after a few years and restarting the cycle at another place. According to an FAO estimate, this form of cultivation dates back to the Neolithic period. While this practice has gradually tended to disappear from states like Bihar, Orissa, and Madhya Pradesh, the area cleared annually for *Jhuming* may be about 100,000 hectares in Assam and Meghalaya. Observations in Assam hills, indicate that at least 10 centimetres of soil may be washed away even from moderate slopes in each *Jhuming* cycle. One of the factors influencing such indifference to soil care is the fact that the land cleared for *Jhuming* is not owned by the cultivator, whose interest in the land is co-terminus with the cropping cycle. Shifting cultivation as well as growing one crop once in two to three years were two of the ancient methods of overcoming the implications of the law of the diminishing return of the soil in relation to crop yield. In areas with settled cultivation, application of organic wastes and the cultivation of pulse crops and other legumes which can fix atmospheric nitrogen in the soil were the common methods of restoring soil fertility adopted in the past.

Soil conservation

Soil erosion leads to an enormous loss of nutrients. Some calculations show that the annual loss of soil due to erosion is about 6,000 million tonnes and that of nutrients is 2.5 million tonnes of nitrogen, 3.3 million tonnes of phosphorus and 2.6 million tonnes of potash. A portion of these nutrients may get deposited elsewhere. In fact, such loss of nutrients may be the most important cause of water pollution in our country. A major approach to soil conservation has been the construction of contour bunds for the purpose of decreasing erosion, conserving water above the bund and increasing infiltration. We have so far treated, during the various Plan periods, about 13.3 million hectares of agricultural land and 1.2 million hectares of non-agricultural land with various soil conservation measures. While these programmes have been very valuable both for diminishing erosion and providing employment, the agricultural benefits from such programmes have not been commensurate either with the effort or expenditure involved. Often bunding has neither been followed up with other measures like providing a vegetation cover nor has it been carried out with an understanding of crop production technology. For example, a recent survey by the Madhya Pradesh Department of Agriculture on the effectiveness of contour bunds in increasing *rabi* wheat yields has shown that on the whole the effect of bunding was strongly negative. Similarly, a study on the effect of bunding on the yield of *kharif* crops in the Bellary area indicated that contour bunding decreased the yields of *jowar*, cotton and safflower both as a result of water stagnation and delay in cultural operations. It is obvious therefore that soil conservation measures need to be planned and implemented in a much more scientific manner taking into consideration not only the need to check erosion, but also the end purpose of promoting crop growth.

One has only to see how land is being used for brick making and road making in our country to understand the extent of indifference to the care of the soil. While planned use of land for brick making could help in building up permanent assets like tanks, unplanned use results both in the loss of good agricultural land and in erosion. Similarly, there is always a danger that natural drains may be plugged if a total view on soil and water conservation is not taken while planning the construction of roads and railway lines. Closing natural drains leads to floods and thereby to considerable soil erosion. Thus, deforestation, shifting cultivation, overgrazing and improper cropping of undulating lands, bunding without vegetation cover, plugging of natural drains and other kinds of poor land management are causing increased runoff, reduced ground water recharge and severe erosion resulting in the deterioration of soil, loss of valuable nutrients, lower yields, flooding of lowland areas, sedimentation of small tanks and large reservoirs and the wastage of precious water to the ocean. It is not hence surprising that in an article entitled *The Eleventh Commandment*, Dr. W.C. Lowdermilk stated a few years

capita meat intake, so as to reduce the pressure on plant proteins which are needed to feed animals, food technologists are now developing textured vegetable proteins resembling meat products. Plant proteins which were not formerly of value in human nutrition are also now becoming usable due to the removal by processing of the toxic or anti-nutritional factor. For example, a milling technique called the Liquid Cyclone Process can help to remove gossypol from cotton seeds. Methods for removing the toxic glucosinolates present in rape and mustard seeds have been standardised in Sweden. Such detoxified rapeseed protein has still some anti-nutritional factors, which are currently being studied. A low cost 65 per cent protein concentrate can now be prepared from fresh coconuts. The process gives at the same time a high grade oil. The Central Food Technological Research Laboratory at Mysore has standardised several useful milling and processing techniques and the improved methods of pulse milling particularly deserve popularisation since they can save over 10% of milling losses.

Changes in processing and utilisation can completely change the market value of a commodity. For example, until some years ago research for the improvement of *robusta* coffee had been given less importance in our country on the assumption that the world demand would be only for *arabica* coffee, which has a superior flavour. The advent of instant or soluble coffee has however changed the position, since *robusta* has good solubility. Thus, while the annual average prices secured in 1961 in export auctions per 50 kg. of similar grades of *arabica* and *robusta* were respectively Rs. 144.50 and 70.50, these prices were Rs. 223 and 220.50, during 1970-71 thus practically wiping out the difference. Similarly, lac was regarded until recently as a dying industry. However, the price of a tonne of lac in the U.K. market this month is £ 1450, while in October 1971, the price was only £ 340. Obviously, some important new use for lac has been found. Demand for tapioca has also greatly grown and it is expected that by 1980, countries of the European Economic Community would be importing at least 4.4 million tonnes of tapioca. These few examples would be sufficient to indicate how in order both to maintain and develop further markets for agricultural produce, we have to keep ourselves very well informed about trends in processing and utilisation. Quality control and improved packaging and forwarding techniques are equally important. All this will call for an Agricultural Technology and Market Intelligence Unit which can keep our research workers constantly informed about the relative priorities they should assign to problems having a bearing on export trade.

Watching technological trends would also be important to stabilise the home market for labour-intensive cash crops in the dry farming regions, such as cotton. Globally, it is becoming clear that cotton may waste by anaerobic fermentation are some of the possibilities under economic assessment in several countries. Unlike the situation in rich nations, non-commercial sources of energy comprising dung, fire wood and crop wastes constitute the major sources of energy supply in rural India and we can hence profit greatly from recent developments on the efficient use of wastes to supply power.

Fertilizer use efficiency is very low at present and the common assumption of return from the applied nutrients is 10 kg. of grain per kg. of NPK nutrients. Scope for improving fertilizer use efficiency exists through procedures like adjusting fertilizer doses to soil test values, better water management, weed control, split application, placing the fertilizer a little below the soil surface, and use of nitrification inhibitors where leaching losses are likely to be high. Seed-cum-fertilizer drills help to achieve good seed germination and fertilizer distribution. When yields increase, deficiency of phosphorous and of micronutrients like zinc become important, as was seen in the Punjab after the introduction of high-yielding varieties of wheat. A continuous monitoring of the status of soil fertility is hence important.

There is apprehension that phosphorus reserves may get greatly depleted by the end of this century. Hence, every attempt should be made to use wastes like basic slag from steel mills, sources like rock phosphate and Laccadive sands and also promote the solubilization of insoluble phosphates through microbial secretion of organic acids which dissolve phosphates. Rock phosphates and basic slag have been found to be suitable for application in acid soils. Acid soils fortunately occur in the vicinity of steel factories and hence transportation costs can be minimised.

Cutting post-harvest losses

Techniques are also becoming available for minimising losses during harvest and post-harvest operations. A major problem in the safe storage of grains is the high moisture content often found, particularly in paddy. Studies carried out at the Paddy Processing Centre, Tiruvarur, on the effects of salt sprays both before and after harvests have shown that this technique could help to bring down the moisture content to about 12 per cent rapidly. We need much more work on the standardisation of effective methods of preventing pre-and post-harvest losses in grains, fruits and vegetables under different ecological conditions. Bad storage not only results in a quantitative loss of all food material, but more importantly, there could be considerable deterioration in nutritive quality. The problem is acute in crops like groundnut which develop aflatoxins following fungal infection.

The situation in processing and utilisation is dynamic. In some of the rich nations, where there is a move towards reducing the total per

ago that "the use of land is a down-to-earth index of a civilization, for land has been the silent partner in the rise and fall of civilizations".

We can continue to neglect our soil only at the peril of our future. The authors of *Limits to Growth* have calculated that every child born today would need 0.08 hectare of land for purposes like housing, roads, waste disposal, power supply and other uses and 0.4 hectare of land for producing the food he or she needs. On this formula, we will need at least 5 million hectares of additional land every year to cater to the needs of those added to our population. In contrast even in 1969-70, the availability of agricultural land was only 0.34 hectare per person. Obviously, it is time we woke up and spread throughout the country a consciousness of the value of soil and the importance of scientific land use.

Improper and inefficient water use, inadequate tapping of sunlight, poor utilisation of biological nitrogen fixation, wasteful disposal of wastes, lack of understanding of recycling processes and poor integration of crop and animal husbandry on the one hand, and terrestrial and aquatic production systems, on the other, are some of our other major liabilities.

The slow pace of progress in getting the best out of our water resources is evident both from the relative stagnation in *kharif* crop production and the low intensity of farming. During the *kharif* season, when much of the rainfall is received, the production of foodgrains was 65.6 and 62.0 million tonnes in 1964-65 and 1971-72, respectively. In contrast, the *rabi* production during these two years was respectively 23.7 and 42.7 million tonnes. Thus, our major grains in production have come from the non-rainy season. With the development of irrigation facilities it should have been possible to bring more area under double and multiple cropping, thereby raising the intensity of cropping. The intensity of cropping is however still low, and has risen from 114 per cent in 1965-66 to only 117 per cent in 1969-70.

A low intensity of cropping even when water is available also implies a poor utilisation of sunlight, since in the tropics and sub-tropics green plants can be made to produce food, feed and fodder continuously by photosynthesis from water and atmospheric carbon dioxide. The cellulose produced by photosynthesis on the earth is not only the chief basis of all fossil fuels, but is also the most abundant renewable raw material currently available.

Nutrient supply

In the area of nutrient supply to crops, organic manures like farmyard manure, compost, green manure, various oil-cakes and various waste products of animal origin like dried blood, bones, fish manure and urine had been used in the past. With the growth in population, farmyard manure and other organic wastes have increasingly been diverted to fuel purposes. Though some work has been done on the generation of gas from such wastes in order to obtain both fuel and manure from the same material, such techniques have not come into use on any significant scale. Much of the urban wastes, sewage water, cattle and human urine and human excreta are not recycled in a manner that will promote productivity.

A great marvel of nature is the way in which micro-organisms fix atmospheric nitrogen in the soil largely through leguminous plants. While synthetic nitrogen-fertilizer production requires very high temperature and pressure for combining nitrogen, hydrogen and oxygen, the nitrogen-fixing organisms like *Azotobacter*, *Rhizobium*, and blue-green algae are able to do this at ordinary soil temperature and pressure, with the help of the enzyme nitrogenase. Nitrogen is now being introduced into the earth in fixed form at the rate of about 92 million tonnes per year, whereas the total amount being denitrified and returned to the atmosphere is only about 83 million tonnes per year. The difference of 9 million tonnes per year may represent the rate at which fixed nitrogen is building up in the soil, ground water, rivers, lakes and oceans. Unfortunately, studies show that while Australia, the United States and Soviet Union are adding every year substantial nitrogen to their soils, we have a negative nitrogen balance to the extent of 8.2 lakh tonnes per year.

Before I end this discussion on our agricultural assets and liabilities, I must refer to the most important factor which will determine our agricultural future, namely, our human population. The principal characteristics of our population are the predominance of youth, poverty, under-nutrition and illiteracy. According to the projections of the Registrar General, we will have about 657 million people by 1981 over 40 per cent of them will be below the age of 18. Nearly 80.0% of our population lived in villages during 1971. We are thus mainly a land of youth and of rural people. Impressive statistics on poverty are available and there is also a growing awareness of the implications of protein-calorie malnutrition on national development. Many authorities now compare nutrition education respectively to the hard and soft ware components of technology. Although in terms of percentage, the number of literates rose from 24.03 in 1961 to 29.34 in 1971, the number of illiterates increased in absolute number during this period. Most of our agriculture is managed by illiterate peasantry and Mahatma Gandhi warned us forty years ago that unless there was a marriage between intellect and labour in rural India, there would be neither agrarian advance nor rural prosperity. Our agricultural future will hence depend to a great extent on how successful we are in involving youth and the illiterate both men and women in rural transformation. The urgency of population stabilisation hardly needs any emphasis, since all our efforts will have no effect in improving the

Biological control of pests

Biological control involving the control of pests through their natural enemies is receiving increasing attention. In the past, more emphasis had been placed on an inundation approach involving the mass breeding and release of indigenous natural enemies. Emphasis is now shifting to obtaining more effective parasites and predators from other areas where the same or related pests occur. In general, countries which have had the greatest successes in biological control are the ones which have imported the greatest number of natural enemies. A station of the Commonwealth Institute of Biological Control located at Bangalore has been helping in getting natural enemies of pests of apple, cabbage, castor, coconut, cotton, potato, sugarcane, rice and aquatic weeds from other parts of the world. Predatory snails and hermit crabs have been found to be useful in controlling the Giant African snail, which had become a menace in Andaman islands and in parts of Kerala and Assam. Attempts are in progress in some countries in Africa to control serious water weeds like water hyacinth and *Salvinia* through introduced parasites. If such parasites prove to be highly host-specific, we may also be able to initiate similar studies in our country, since these aquatic weeds are causing serious problems in tanks and waterways particularly in eastern India and Kerala.

Economy through recycling

The third main concept I should like to touch upon is economy and maximisation of farm income, a concept which is being used with great profit in diverse areas like increasing the efficiency of nutrient supply, water use, energy release through recycling and effective use of all wastes and by-products, improved harvesting, storage, processing and utilisation. The major aim is to reduce waste in all possible ways and decrease to the extent possible the dependence on non-renewable resources for increasing production. An integrated nutrient supply system involves the development in each Block of an appropriate schedule of manuring with organic and inorganic manures. There is great scope for raising leguminous shrubs on bunds of irrigated fields or all along irrigation canals and rivers for providing green leaf manure. It would be wise to introduce pulses and fodder legumes in all rotations. Success in conserving cow dung and other wastes for use as manure will depend upon the availability of fuel.

Devices like cow dung gas plants are yet to become popular. Meanwhile, rapid technological progress is taking place in which all wastes which contain cellulose can be converted into pipeline gas or liquid fuels. The conversion of grains through fermentation into usable ethyl alcohol, the growing of trees specifically for generating thermal power, the development of new high-yielding crops for industrial energy and recycling animal

Harmony and natural balance

The next concept I would like to deal with is harmony and natural balance. This involves the development of management concepts in areas like disease and pest control and the balanced growth of different components of a production system. "Prevention is better than cure" is the general motto in disease control and we know that through appropriate immunisation, and sanitary and quarantine measures the health of farm animals can be maintained at a satisfactory level. Our scientists have been developing effective vaccines against the important diseases of cattle. Recently, a vaccine against lung worm of sheep has been developed using the principle of radiation attenuation. In general, however, the awareness of the need for quarantine and sanitation is not widespread.

Depending upon the cropping pattern, water availability and marketability of produce, profitable mixed farming systems can be developed. Where feed grain availability is low, ruminating animal could form a good mix with cereal and millet cultivation. Poultry rations usually contain as high as 60 to 70 per cent cereal grains. However, several agricultural and industrial by-products like rice bran, wheat bran, slaughter-house waste, fishery wastes, etc. could be used as poultry feed. Similarly, last year's serious drought in Maharashtra provided an opportunity for introducing new rations like a mixture of bagasse, molasses and urea. Improved strains of fodder grasses and legumes are also becoming available and studies at the National Dairy Research Institute have shown that high-yielding cross-bred cows can be maintained largely on high quality fodder.

Growingly, concepts like pest control are giving way to procedures which help to raise good crops through better management with minimal assistance from chemical methods of control. Such integrated procedures of pest management involve an appropriate combination among methods like selection of resistant varieties, use of parasites and predators, both native and introduced, ecological control through modifications in cropping systems and agronomic practices, development of microbial pesticides, use of attractants and repellants including sex hormones, development of various methods of inducing sterility and use of selective chemical insecticides. Such an integrated approach has become necessary to avoid dangers arising from the destruction of beneficial insects and natural enemies of pests, the persistence of some pesticides in the food chain, the origin of pesticide resistant insects and environmental contamination. Safer chemical pesticides are also being developed and in crops like *jowar* the control of shoot fly through either treating seeds with a suitable pesticide or an adjustment in date of sowing could make a big difference in yield.

quality of life, if population growth cannot be arrested and stabilised.

The second class compartment of Spaceship earth is getting smaller and smaller, while the number of those who have to live there is getting larger and larger. Affluence is becoming a major claimant of world food and energy resources. Between 1967 and 1971, the developed market economics increased their agricultural exports on an average by 11 per cent per year, while the developing countries lost ground by 1 per cent. This is the net result of what is called the U.N. Development Decade. It is time the people living in the first class compartment realised that when the compartment of the poor bursts due to excessive pressure, the whole spaceship will crash. But the poor have to begin helping themselves.

During the last few years, we have started making real progress in improving our agricultural capability. While food production dropped by 17 million tonnes during the drought of 1965-66, the fall in production during the drought of 1972 is likely to be less than half of this amount. This is certainly an index of real progress and encouragement for greater effort.

To summarise the state of our agricultural balance sheet, we are endowed with considerable ecological diversity, a large volume of tapped and untapped sources of water, abundant sunlight, and large animal and human populations. Our liabilities, apart from those caused by population growth and aberrant weather, mostly arise from an improper use and management of these resources. Attempts to promote synergy, which is the only mechanism which can lead to rapid progress from small resources, have been few and halting. Our urgent needs hence are first, to develop and introduce in each ecological area an agricultural production technology which will lead to increased productivity based predominantly on the use of renewable resources and on the wise husbanding of non-renewable resources. We will have to learn to produce more and more food from less and less land. Secondly, we need to develop and introduce educational tools which will help to impart the latest technical skills to illiterate peasantry and which will enable educated youth to become catalysts of rural change. Finally, we need to develop and spread management and organisational techniques which will help those living in absolute poverty to overcome their handicaps and obtain their share of the fruits of agricultural advance. I shall deal with recent developments in agricultural science in the second lecture and with the social and educational aspects in the final lecture.

2

The Emerging Agricultural Technology

In the first lecture in this series, I attempted to give a synoptic view of our agricultural assets and liabilities and stressed that in view of the inelastic nature of land availability and the competing demands for its use, we have to adopt an agricultural technology which will help us to achieve our immediate goals of more food, more jobs and more income for the present population, without at the same time endangering the long term production potential of the soil. It is probable that extensive ocean farming, hydroponics or soil-less cultivation, test-tube cultivation, protein from petroleum and single cells and other similar techniques may contribute to our future food supply. In the immediate future, however, we will have to rely primarily on mother earth to feed us and our animals. As far as we can judge now, soil will continue to be the most important medium for crop growth, since several of the other techniques will have to rely heavily on the use of non-renewable resources of energy. We also do not know what the long term consequences of certain trends in ocean farming, such as induced upwelling, will be. Upwelling is a physical, ocean-atmosphere process leading to the transfer of high concentrations of chemical nutrients from sea bottom into the zone where there is active carbon assimilation thereby producing food for fish. It has been estimated that about half of the world's fish production occurs in the restricted coastal upwelling areas. If man can artificially create upwelling, it is possible that there may be richer harvests of marine life for some time. No one, however, can predict what will happen in the long term. We already have the lesson of the Peruvian fisheries to remind us that if man in his greed tries to over-exploit a resource he will come to grief. In 1970, the catch of anchovies in Peru reached 12.3 million tonnes. It dropped dramatically to about 4 million tonnes in 1972 and is not yet showing any sign of recovery. Though the drop is partly due to a periodic ecological disturbance in the sea leading to the influx of warmer water, many authorities believe that over-fishing

in oilseed production. Apart from opening up the possibilities for sunflower and soybean production, we have not had so far any striking advance in oilseed research. Scope however exists for improving the yield of groundnut, *til*, safflower and coconut, through better management and seeds. However, in the near future we may have to lean heavily on increasing the acreage under oilseed crops, if we are to substantially increase the production of these crops. More or less similar is the position with regard to pulses. Increasing the area under oilseeds and pulses would be possible only through multiple cropping and by increasing the productivity of crops like rice and *jowar*, so that some land can be released from them.

More area for pulses, oilseeds

There is considerable scope for releasing areas from *jowar* and *bajra* for pulses or oilseeds in rainfed areas by improving the productivity of these crops, replacing the old varieties by high-yielding ones. For example, calculations show that in Gujarat, which produced during 1969-70 one million tonnes of *bajra* from 1.73 million hectares, it is possible to produce 1.12 million tonnes from 1.60 million hectares merely by increasing the proportion of the area under high-yielding hybrids from the original 17 to 30 per cent. Similar opportunities are now available in *jowar*, as a result of release of varieties like 302, 604 and *Swarna*.

Genetic improvement of nutritive quality of basic staples is another venue of providing better nutrition, at no extra cost. Chemical fortification with limiting amino acids, which used to be the major approach advocated ten years ago, has given way now to attempts to improve genetically the amino acid balance and nutritive quality of crops like maize, *jowar*, barley, potato, wheat, and rice. This field of research was stimulated by the discovery at the Purdue University in the United States of genes conferring a higher content of lysine, an essential amino acid, in the protein of certain strains of maize a few years ago and more recently in *jowar*. The finding in *jowar* was made by an Indian scientist, Dr. Rameshwar Singh of Pant Nagar, while he was working at Purdue. This is of particular significance since the nutritional disorder Pellagra has been found by the National Institute of Nutrition, Hyderabad, in areas where *jowar* is the staple. Another important finding in this area is the identification in Sweden of a barley strain with high protein and lysine. It is interesting that both the *jowar* and barley lines originated in Ethiopia. This line of research may help to produce high yielding-cum-high nutritive quality strains. If it is coupled with the widespread preparation of home-made weaning foods such as the Hyderabad mix in villages on the basis of locally available cereals, pulses and jaggery, a dent on the malnutrition problem can be more easily made.

enduring type. He is also trying to develop escape mechanisms by trying to alter the growth phase of the plant in such a way that it does not synchronise with the peak multiplication and infectious phase of the pathogen. He is striving to develop strains called "composite varieties" which can help to reduce the pressure on the pathogen in building up new and virulent races. He is also trying to understand the biochemistry and physiology of resistance, hoping in this way to find effective and cheap chemical methods of control. While all these approaches need to be followed with vigour, our immediate hopes lie in the genes for resistance found in the primitive cultivars and other wild and cultivated genetic material occurring particularly in the centres of diversity of plants. Thus, the rich collections of rice made by our scientists from the north-eastern Himalayas contain genes for resistance to a wide range of pests and pathogens infecting rice. Areas where the pests are endemic provide opportunities for screening for resistance. Under our All-India Co-ordinated research programmes, such areas have been identified, and given an efficient seed multiplication and distribution machinery, we should be able to remain ahead of the pathogen in several crops.

Equally exciting are the opportunities now available for adding a nutritional dimension to crop improvement programmes. According to several authorities, including Drs. C. Gopalan and P.V. Sukhatme of our country, malnutrition in countries which have cereals as the staple food, is mostly the result of under-nutrition, arising in turn from inadequate purchasing power. Chronic illness and worm infection due to insanitary conditions, lack of community health care and ignorance about the feeding of infants resulting from poverty all add to the problem. According to the report of the Task Force on Nutrition of the National Committee on Science and Technology, 90 per cent of our pre-school children have heights and weights much lower than those of children of corresponding ages in the United States. Another important point made by the Task Force is that our nutritional problems are qualitatively very different from those of the richer nations and hence the remedies must be our own. For example, in richer nations, where excessive intake of fat of the order of 75 to 100 g. daily has aggravated the problem of certain kinds of heart diseases, the emphasis has rightly been on reducing the fat content of the diet. The same situation holds good among the rich in our country. This section of the population, however, is very small and for a majority of our people, the inclusion of more fat in the diet is not only desirable but necessary. This is because fats and oils are not only concenrated sources of calories but act as important vehicles for some vitamins. The NCST Task Force has hence recommended that we should try to raise the per capita average consumption of fats from the current level of 10 g. per day to at least 30 to 40 g. per day. This would call for a 3 to 4 fold increase

leading to the depletion of the basic renewal stock may also be a factor responsible for this big drop. A sad consequence of the drop in the availability of anchovies along the Peruvian coast is the dwindling in the population of the Guano birds, from about 30 million a few years ago to about a million now. If the Guano birds disappear, the finest natural fertilizer in the world formed by the deposits of these birds will also gradually get exhausted. Anchovies not only constitute the dominant food of the Guanos, but also of poultry and pigs in North America. The drop in the availability of anchovies hence escalated the demand for soyabean as the main protein source in animal feed mixtures. The consequent sudden rise in soyabean price led the Japanese to release rice for animal feed, rather than import soyabean at very high prices. This illustrates the inter-dependence of biological and production factors and the consequences of one adverse event on other seemingly unrelated events.

The importance of the scientific management of the biosphere is thus obvious. In this lecture, I would like to deal with some recent trends in the promotion and management of biological productivity citing relevant situations in our country.

Attention to economic ecology

First among the emerging concepts of management of biological assets is attention to economic ecology. I used the prefix "economic" before "ecology" to underline the fact that what we need is as high an economic growth rate as possible through the use of the principles of ecology rather than the kind of ecology discussed frequently in the affluent nations which is of the conservationist or Zero growth rate kind, intended to preserve the high standards of living already achieved. For the sake of convenience, I would like to deal with our arable land in five groups—arid, semi-arid, humid, irrigated and hilly regions. It is obvious that there are numerous climatic variations in these groups. *Kharif* and *rabi* seasons have not the same significance in south India, as they have in the north. This is why agricultural technology becomes highly location and situation specific, necessitating a considerable amount of local research and testing work, before a new technology can be recommended to the farmers. While ideas and concepts can be transplanted from one region to another, the actual material and techniques will have to be tailored to suit the local agro-ecological and socio-economic milieu.

The arid zone occupies in our country an area of 3.2 lakh sq. km. of hot desert, mostly in Rajasthan, Gujarat, Haryana and Mysore and 0.7 lakh sq. km. of cold desert in Ladakh. In Ladakh, extreme aridity combined with low temperature limits the possibility of growing crops to about 5 months in a year. Hence, the strategy for agricultural growth in

Ladakh has to depend largely on the cultivation of quick-growing cereals, oilseeds and fodder crops and the rearing of goats, giving Pashmina wool. The hot desert regions, in contrast, have an abundance of sunshine, land and soils capable of responding to management, well adapted grasses and trees, excellent breeds of sheep, goat and cattle and considerable reserves of ground water. Water and not land, is the principal limiting factor and hence all attempts have to be focussed on maximising income per litre of water. This will be possible only if the ecological balance is not further disturbed and a proper land use pattern is adopted.

Let me cite three examples to illustrate the trends which are aggravating the unfavourable consequences of aridity. First, the area used exclusively for grazing in Western Rajasthan has dropped from 13.09 million hectares to 11.04 million hectares during 1951-61, while the population of grazing animals increased during the same period from 9.4 million to 14.4 million. The same trend of diminishing grazing area and rapidly expanding grazing population is still persisting. Secondly, while most of the land in the arid zone is fit only for forestry or range management, land is increasingly being brought under cropping. The areas cropped rose from 26 per cent in 1960 to 38 per cent in 1970, thus extending cultivation even to sub-marginal areas. Thirdly, the area under forests is only 2 per cent although the extent of land classified under barren uncultivable waste is 28 per cent and cultural waste is 18 per cent, all of which could be planted with tree species like *Acacia tortilis*, *Prosopis juliflora* and *Eucalyptus* sp. Fruit trees like *ber* and pomegranate can also be grown extensively.

Reclaiming the desert

Afforestation has to be the focal point for reclaiming the desert. Techniques for soil and water conservation and for sand dune stabilization are fortunately available today. Large scale planting of shelter-belts could help to minimise wind erosion and decrease the dust over the desert. Scope for the establishment of pastures and grazing lands is great and strip cropping involving the setting up of permanent grass strips to prevent wind damage will help to increase the yield of crops like *bajra* and *moong* substantially. If steps of this kind can be taken, it may be possible for the nomadic tribes like Banjaras and the Gadiya Lohars to start leading a more settled life.

Rajasthan has many fine breeds of sheep and research has shown that appropriate cross-breeding precedures can help to improve the yield and quality of wool as of mutton. Fortunately, techniques for artificial insemination have been developed and hence more widespread genetic improvement programmes are possible.

An important need in the desert areas is the preservation of organic

per square metre can be packed into the new varieties of wheat and rice, as compared to the old ones. Similarly, the distribution of the total dry matter produced by the plant between the part of commercial value and the remaining parts is much more favourable in the new strains. New plant types in *bajra* can respond to a population density of about 250,000 plants per hectare, in contrast to less than 100,000 plants in the case of the earlier strains. Similarly, in maize, dwarf varieties with smaller tassel, high nitrate-reductase activity and upper placement of the ear are under testing in several countries and these can respond to a population density of about 150,000 plants per hectare. The concept of population explosion in fields has also permeated horticulture. Growingly, emphasis is being placed in orchards on the selection of dwarfing root stocks. Some experts believe that the fruit orchards of the future may be "Lilliputian" in nature, facilitating a high management efficiency. Unfortunately, in our country root stock consciousness has not yet spread and citrus growers still raise orchards from seedlings although budded plants on appropriate root stocks like trifoliate root stock in drought prone areas can make a great difference in orchard productivity.

Apart from improving population performance and the yield potential of economic plants through a repatterning of plant architecture, growth rhythm and allocation of dry matter between the commercial and non-commercial portions of the plant, the other areas of concern have been in introducing a broad spectrum of resistance to pests and pathogens and in improving nutritional and cooking or processing quality. Unfortunately, breeding for resistance to pests and diseases is often a never-ending task. The resistance tends to break down, following the build-up in nature of new races of the pathogen capable of attacking a variety earlier released for its resistance. We are now witnessing this in the popular wheat varieties Kalyan Sona and Sonalika, which at the time of their release in 1967, had a high degree of resistance to brown and yellow rusts. Kalyan Sona has become susceptible particularly to brown rust and there is no assurance that the resistance of Sonalika may hold out for long. Seeds of new strains have hence to be multiplied and distributed speedily. Dynamic varietal diversification and seed multiplication programmes are essential to sustain a good crop production programme.

Outwitting the pathogen

Will the struggle between the breeder and the pathogen be an endless one or will one outwit the other? This is an interesting question for which no clear-cut answer is yet in sight. The breeder is adopting a multipronged strategy. He is working on a type of resistance, technically referred to as horizontal or field resistance, which is likely to be of a more interactions. Let me cite an example.

Chinese peasants had devised over a thousand years ago methods of producing high yields of fish with low inputs of money and technology. They did this on the basis of two principles. First, a body of water is a three-dimensional growing space. To treat it like a field by planting only one kind of crop is likely to result in wasting the majority of that space. Secondly, any fertile pond will produce a number of different fish food organisms. However, most fish are not omnivorous, but are rather selective in their diet. Thus, stocking single species in a pond wastes not only space but food. Chinese fish culturists took advantage of these two characteristics of the pond environment through polyculture or stocking several types of fish. Recently, under an All-India Co-ordinated Project on composite fish culture, suitable species of fish have been identified which can give co-operatively about 3,000 kg. of fish per hectare in about 6 months. The species involved are both Indian carps like *catla*, *rohu* and *mrigal* and exotic carps like *grass carp*, *silver carp* and common carp. Such high synergy aquaculture systems can revolutionise fresh water fish production in our country.

Terrestrial and aquaculture systems can also be devised, where each element would contribute significantly to the functioning of the whole, resulting in a profitable farm ecosystem. The Chinese have again taken advantage of the possibility for raising pigs and ducks in conjunction with the culturing of fishes. In a 4.4 hectare Chinese farm in Malaysia, pigs, fish and aquatic plants were raised together. About 30 tonnes of pig meat were produced per year, with the primary feed being the aquatic water spinach, *Ipomoea repens* which grew luxuriantly in the fish ponds fertilized by the pig manure. Besides the pigs, some 3000 kg. of fish were cultured in the small ponds. The main food for the fish was algae, which grew well in the enriched ponds. Ducks could complement a system like this, their wastes being added to the ponds.

Changing plant architecture

The search for synergy has led both to the re-patterning of plant architecture in many economic plants and to the development of cross-bred farm animals which are efficient in the conversion of feed into the product for which they are raised by man. What the breeders now look for are the plant types which can maximise production per unit of area, time and water. Thus, plant types which will not shade each other or fall over each other and which will promote better light interception and carbon dioxide fixation are now sought after. In the earlier strains, many of the characteristics had been selected for performance under adverse circumstances and not for high yield under good management. Because of their plant and leaf characters, a larger number of productive tillers

matter for the soil. Unfortunately, due to deficiency of fuel, the available organic wastes are generally used for burning and trees are cut in an unplanned manner. It is here that more extensive research and extension efforts on the utilisation of solar energy for purposes like heating, cooking, lighting and distilling water will be of great value. Often in the desert areas, the water is saline and people have to walk several miles every day to fetch sweet water. Solar stills to produce water for drinking in such area will be a great boon to the villagers.

Sophisticated techniques for raising crops in desert areas with very limited quantities of water are now becoming available. These involve cultivation of vegetables and high value crops under air-inflated polyethylene houses using economic methods of water supply like drip or sprinkler irrigation. Since the Lathi aquifers of the Thar desert are rich, it may be possible to develop efficient water use systems at least for raising community nurseries of different crops so that transplanting can be done if there is a delayed onset of monsoon and for purposes like the cultivation of vegetables and seed production.

Unfortunately, we have no arrangements now either to mitigate the rigour of a bad season or to derive maximum advantage from a good season. For example, this year provided a unique opportunity for planting in the desert a large number of trees and for seeding large areas with grasses. While the average annual rainfall of Barmer and Jaisalmer districts are 277.5 mm. and 164.0 mm. respectively, 302 mm. rain was received in just three days in Barmer and 377 mm. in Jaisalmer between 10.8.73 and 31.8.73. In spite of the shallow nature of the soils and the calcium carbonate pans which occur in the subsoil, thereby increasing run-off and reducing infiltration, abundant moisture was available to facilitate the establishment of trees, shrubs and grasses. The district administration tried its best for getting the available seeds sown, but the magnitude of the programme was small in relation to the opportunities that were available.

"Good weather code"

What we need in such areas is a *Good Weather Code*, which will spell out the types of activities that should be undertaken in the event of rainfall being good. While we have Scarcity Manuals which tell us what to do when rains fail, we do not yet have a corresponding action code to indicate what we should do to capitalise on good weather. It is obvious that a written code by itself will be of no value, if arrangements to implement its provisions, by way of extensive nurseries of trees, do not exist.

About 75 per cent of our cultivated area is rainfed and since about 42 per cent of our food comes from such areas, there is variation in food production depending upon the amount and distribution of rainfall. Semi-arid areas where them can annual potential evapotranspiration exceeds the mean annual rainfall, occur in many of our States. Such areas have been plagued for centuries by periodic droughts, floods, soil erosion, instability in production, drinking water scarcity, unemployment, under-employment and other forms of human suffering. In about 101 million hectares, crop fortunes are closely linked to the behaviour of the monsoon. These areas not only provide much of our millet and pulses but are also the major suppliers of industrial raw material like cotton and groundnut.

The earliest research effort on dryland agriculture was started by Tamhane in 1923 at Manjri. Subsequently, a rather comprehensive programme was evolved by Kanitkar for improving the productivity of rain-fed farming. This formed the basis for the Dry Farming Scheme started in 1933 by the Indian Council of Agricultural Research at Rohtak, Sholapur, Bijapur, Raichur and Hagari. The outcome of these projects was a series of dry farming practices commonly known as Bombay, Hyderabad and and Madras Dry Farming Practices. The basic features of the dry farming practices developed in the past were bunding to conserve soil moisture, application of farmyard manure to supply plant nutrients, deep ploughing once in three years, shallow preparatory cultivation and interculture, low seed rate and wide spacing of crops. Official estimates placed the increase in crop yields due to the adoption of this package of practices at about 15 to 20 per cent over a base level of 200 to 400 kg. per hectare. No wonder, the package failed to catch the imagination and interests of the farming community. Nevertheless, these programmes did make a useful contribution in the areas of moisture conservation and erosion control.

Later in 1954, Soil Conservation Research and Demonstration Centres were established in different parts of the country and they gathered valuable data on the capability of land, rainfall intensity and distribution, run-off patterns and response to fertilizer application. In addition to developing conservation practices appropriate to a region, these centres also provided an insight into the factors limiting production in dry-farming areas. Lack of quick maturing varieties was a major handicap in the early programmes. For instance, it was noted at the Bellary Research Centre that in late December the soil, which has a high clay content, cracks heavily due to the loss of moisture. The flowering stage of the traditional varieties of cotton and *jowar* coincided with this period of rapid soil drying and hence their yields were poor. It was thus obvious that if cotton or *jowar* varieties which could be harvested by early December could be introduced into cultivation much higher yields could be obtained. We had to wait until 1965 when thanks to hybrid *jowar* CSH.1, H.B.1 *bajra* and PRS cotton varieties, which could all mature before the soil lost its

We need for such flood-prone areas a *Flood Avoidance Code*, which could provide guidelines for restructuring the agricultural system in accordance with the probability of occurrence of floods.

The entire riverine or *Diara* areas of Bihar and Uttar Pradesh will benefit greatly from arrangements for community tube wells. The Chhota-Nagpur and Santhal Parganas area can grow fruits, vegetables and develop dairying so as to capture the emerging market in cities like Bokaro. We also know now that due to cloudy conditions and relatively greater incidence of pests and diseases during *kharif*, the yield of high-yielding varieties of rice is lower during this season than during *rabi*. Yet, while the total area under rice is over 37.0 million hectares, the area under *rabi* rice is only about 3 million hectares. The major problems in extending *rabi* rice cultivation are the cold temperatures of December to February and scarcity of water. Cold-tolerant strains are currently being selected and with more economical water management for which techniques are available, it should be possible to take a good *rabi* rice crop in the delta region of the east coast, where ground water is available a few metres below the ground. Thus, the scope for re-structuring cropping patterns on ecological and marketing considerations is vast. For this, we need to classify the existing cropping systems, which are largely the product of the home needs of the farmer and pest and disease syndromes, into classes such as those with high yield potential and low risk, high yield potential and high risk, low yield potential and low risk, and low yield potential and high risk. Obviously, we should strive to eliminate the low yield potential crops from the cropping system of each area and reduce the risk elements in the high yield potential crops. Above all, effective purchase and marketing arrangements are vital, since the farmer is motivated not so much by yield per hectare but by net return per hectare.

Synergy in agriculture

Having discussed some of the broad features of crop planning on an ecological basis, I would like to turn to the application of three other important concepts in agriculture. The first of these is the concept of synergy in agriculture, one of the most fascinating scientific developments of recent years. Synergy is not a new concept, since this mechanism, which results in the product being something much more than the sum of the parts, has been the most potent tool involved in natural evolution. Symbiosis, or mutually beneficial relationships and co-ordinated functioning are essential ingredients of synergy. For developing high synergy cropping systems, an understanding of population behaviour and performance, rather than merely of the characteristics of individual plants or animals, is essential. Prudent observers of nature in the past had devised biological systems based on the release of synergistic

High-altitude research

High altitude areas have also received relatively little scientific attention. Ecological conditions vary greatly even within short distances in these areas depending upon aspect, latitude, altitude, slope, soil depth and distance from the plains. Large variations in temperature and rainfall occur and the length of growing season is controlled by the time of occurrence of snow in winter and its disappearance in the spring. Erosion will be a serious problem and in several of these areas, data are needed on minimum tillage, suitable implements to ensure timeliness of operations, fertilizer use and weed control. Both horticulture and nomadic sheep husbandry require considerable attention. For agriculture to start moving in these areas, marketing arrangements are pre-requisites, since in some of the Himalayan regions due to a variety of reasons the producer may get as little as 10 percent of the price paid by the consumer.

Besides rainfall, altitude and latitude, the ecological conditions of soil and season need understanding for the improvement of biological productivity. We have large areas affected by salinity and alkalinity where crops either do not grow or give very poor yield. Soil salinity is also becoming a problem in black soils, where irrigation facilities have been developed recently. An understanding of the nature of the problem and of the physical and chemical characteristics of the soil profile would be necessary to introduce the most appropriate corrective measures like gypsum application, drainage, crop and varietal choice and fertilizer use. Fortunately we now have techniques available for reclaiming such problem soils as a result of the work done at the Central Soil Salinity Research Institute, Karnal, and at other research centres and agricultural universities. Acid soils also require special care and in particular, the most effective methods of phosphorus application will have to be worked out.

Strategies for ecological seasons

We are yet to work out detailed production strategies for each ecological season. We now know, for example, that in Assam, the period between September to May is usually free of floods, since the major floods have either taken place in May-June or more commonly in August. There is tremendous potential in this area for exploiting ground water and for arranging for lift irrigation. An assured *rabi* crop can be taken if arrangements can be made to supply water. There are areas in Assam with over 250 mm. winter rains, where even pending the establishment of an irrigation system, good crops of sunflower, soybean, barley, *moong*. and even a short duration rice variety like *Bala* or *Pusa 2-21* can be taken. Similarly, coastal areas or West Bengal, Orissa and Andhra Pradesh are exposed to recurrent floods and cyclones during August-September. It is possible to tailor a cropping pattern which would escape or avoid the fury of floods.

moisture, good yields could be achieved even in years of subnormal rainfall.

Intensification of dryland research

It is experiences of this kind that led to the intensification of dryland farming research in 1970 through the initiation of an All-India Co-ordinated Research Project on Dryland Agriculture with the collaboration of the Government of Canada. Meanwhile, international interest in upgrading the productivity as well as the stability of production of the dry farming regions of Asia, Africa and Latin America grew and resulted in the establishment by the Consultative Group for International Agricultural Research of an International Crops Research Institute for the Semi-arid Tropics at Hyderabad in July, 1972.

The new phase of dry farming research, although only 3 years old, has already resulted in considerable data on better moisture conservation and use, new cropping patterns, crop life-saving techniques and mid-season corrections in crop planning in the drought-prone areas. The pilot project areas attached to the dry farming research centres are helping to identify the socio-economic and operational constraints in the transfer of the technology from the research farm to the farmer's fields.

Since water is the major limiting factor, a priority area of research is the standardisation of techniques by which as much of the precipitation as possible can be conserved for crop use, either directly in the soil profile through infiltration or through run-off collection and storage. Deep ploughing, for example, promotes a vertical rather than a tangential flow of water in red soils with a dense sub-soil. The cultivation of deep rooted crops like castor, Red gram or *arhar* and cotton further helps in improving the soil texture and in adding organic matter through root deposition. Run-off storage structures are being developed both for individual small farms and for larger water sheds. Obviously, the most effective method will be the co-operative management of an entire water shed. If sufficient water can be collected in community owned ponds, a life-saving irrigation can be given at the time of grain formation, when the crop will benefit most from the supply of a little water.

In black soil areas with moderate rainfall, there is scope for double cropping or ratooning, provided suitable surface drainage can be introduced during the rainy season and appropriate tillage practices can be developed. Drainage and sound soil and water management will again need some degree of cooperative endeavour on the part of a water-shed community. There is also great scope for introducing better inter-cropping practices in areas with annual rainfall ranging from 625 to 1000 mm.

Drought-escaping varieties

Progress has been made in identifying crop varieties which are relatively photo-insensitive and which have a shorter duration and the resulting ability to escape droughts. Early seedling vigour and good population performance are the other attributes of such strains. Suitable varieties in rice, *jowar, bajra*, minor millets, sunflower, safflower, castor, mustard, groundnut, pulses like *moong, urad, arhar*, and cowpea and cotton are becoming available. As a result, different cropping patterns can be developed to suit different weather models. For example, some of the common weather aberrations are (a) early or delayed onset of monsoon, (b) long breaks in the monsoon and (c) inadequate rainfall and different crop schedules can be developed for each of these conditions. If the monsoon is very early, short duration legumes could be taken followed by regular season crops. For normal sowing, *jowar*, for late sowing, *bajra*, and for very late sowing *setaria* are some of the possibilities. When there are long breaks in the monsoon, the *jowar* or *bajra* crops affected by drought could be ratooned. Crops with indeterminate growth habits such as castor or *arhar* regenerate fast if given an urea spray after the receipt of rains during a prolonged drought period. The development of early maturing *arhar* varieties like Prabhat and Pusa Ageti has made it possible in north-western U.P. to take a pulse crop before wheat. Since early varieties of *arhar* are now available, a crop of this pulse can be taken in north India between July and December. Then, with the help of dew or winter rains, a crop of sunflower can be raised in the same field from February to April. Much better use of dew can be made in the north India during *rabi*. Dr. R.D. Asana, one of our eminent plant physiologists, developed a model of a wheat plant which would be capable of retaining dew. We need research of this kind in all rainfed *rabi* crops. We should evolve for each soil and rainfall belt a series of alternative cropping patterns to match different weather probabilities. It would also be necessary to build the appropriate seed and fertilizer buffers and organise community nurseries in order to put into practice alternative crop schedules, if the weather proves truant. The National Commission on Agriculture is planning to develop the broad outline for *Drought Code* which could help the developmental administration to be ready for any weather pattern and initiate anticipatory action to mitigate the effects of drought, rather than be content with palliative action after the misfortune has set in.

Multiple and relay cropping

The potential of irrigated areas to produce much higher quantities of food, feed, fibre and fodder plants through multiple and relay cropping is now well known. Due to various difficulties and shortcomings in the water conveyance and delivery system as well as due to shortage of power, fertilizer and good seed, the full potential of the irrigated areas is yet to be realized. If these defects are overcome and minimum of two good

crops can be raised the production of about 8 to 10 tonnes of food and other grains per hectare per year, now being harvested in several of the experimental stations of agricultural universities, should not be beyond the reach of many small farmers. While taking up intensive farming practices, a continuous monitoring of the soil for major and micro-nutrients and for pathogens will be essential. Legumes should find a place in the rotation and as a rule, crops sharing common pests and diseases should not succeed each other. It would be better to alternate deep and shallow rooted crops so as to tap nutrients from different soil layers.

New systems of cropping are rapidly coming into existence in many of our irrigated areas. Thus, in the Punjab and Haryana, rice during *kharif* and wheat during *rabi* is gaining popularity. In West Bengal, wheat is becoming popular as a *rabi* crop in rice fields. Baisakhi *moong* and other strains developed in order to find place for a pulse crop during a season when the land is normally fallow are becoming popular as summer crops. In the rice fallows of South India, *jowar, bajra* and cotton can be raised during the off-seasons. In the case of several of these new cropping patterns, we need much more data on the most appropriate cultural practices including fertilizer application and weed control.

Effective land use

Our knowledge of the most effective land use systems in the heavy rainfall areas is still fragmentary. Many of these areas, Assam, Meghalaya, Arunachal Pradesh, Nagaland, Mizoram, Tripura, Manipur and Kerala grow plantation crops and fruit trees in the medium and higher elevations. A viable alternative to shifting cultivation has to be found in the north-eastern Himalayan region. Similarly in Kerala, there is very little data on the optimum utilisation of garden lands occupied by crops like coconut, arecanut, mango and jackfruit. Prof. K.N. Raj and his colleagues have recently pointed out that the current crop-mix in garden lands of Kerala and Mysore is the product of the technological possibilities as known until now to the farmers of these areas but that a fresh look is needed since. But the market conditions for some products, as for example arecaunt, have considerably changed. By appropriate changes in spacing in cocount and arecanut, some other crops of high value like cocoa, cloves, and soybeans can be grown in between the palms. New varieties of grasses and legumes are available now which can also be grown as inter-crops in the arecanut or coconut plantations so that the farmer can maintain a few cross-bred cows for milk production. These and many other possibilities for capitalising on the ecological possibilities of the humid tropic regions are yet to receive intensive attention.