Changing Nature of the Food Security Challenge: Implications for Agricultural Research and Policy

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Sir John Crawford Memorial Lecture
November 1, 1990
Washington, D.C.

Published by the Consultative Group on International Agricultural Research, CGIAR Secretariat, 1818 H St., N.W., Washington, D.C., 20433, United States. November 1990.

Sir John Crawford Memorial Lecturers

1985 Robert S. McNamara, United States
1986 Bukar Shaib, Nigeria
1987 Amartya Sen, India
1988 Helen Hughes, Australia
1989 Jacques Diouf, Senegal
1990 M. S. Swaminathan, India

The Sir John Crawford Memorial Lecture has been sponsored by the Australian government since 1985 in honor of the distinguished Australian civil servant, educator and agriculturalist who was one of the founders of the Consultative Group on International Agricultural Research (CGIAR). Crawford (1910-84) was also the first chairman of the CGIAR's Technical Advisory Committee.

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M.S. Swaminathan

One day early in 1965 I had a call from an officer of the Planning Commission of the Government of India asking whether I could show a distinguished visitor from the World Bank around the wheat plots at the Indian Agricultural Research Institute (IARI), New Delhi. I asked what exactly the visitor would like to see and how much time he could spare. In reply, Sir John Crawford came on the line himself and said he would like to see the semi-dwarf wheat varieties in order to understand their yield-enhancing potential. I asked whether he would like to see them in the experimental station or on farmers' fields. He immediately replied, "In farmers' fields." I took him to the Jounti Seed Village of IARI where he spent a whole day squatting in farmers' homes drinking the sugarcane juice and eating the pearl millet bread they gave him and enjoying himself thoroughly. At the end of the day when I was taking him to his hotel, he said, "I now see light where there was only darkness."

*Thus began a strong personal friendship which lasted un*til his death. For over 15 years, he was a friend, philosopher and guide to me and my family. I am hence grateful for this opportunity to pay homage to the memory of a truly remarkable person, whose genius lay in his being simultaneously a vertical and a horizontal man. This combination made his summing up of complex facts a combination of clarity, precision, and a delightful mixture of wit and wisdom.

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The recommendations he made on behalf of the Technical Advisory Committee (TAC) to members of the CGIAR were always listened to with great respect and evoked a positive response. He had no peer in foresight about the emerging developments in global agriculture.

I had the good fortune of working with Sir John during my term as Vice-Chairman of TAC during 1971-77. One of the things I learned from him was the continuous quest for excellence and relevance in research and a concern for maintaining sustainable dynamism in older institutions. I am glad the traditions he set up have been not only maintained but have been strengthened further over the years.

Sir John's major obsession both in his work in India and in TAC was the elimination of hunger and poverty through appropriate packages of technology, services and public policies. He felt that a high priority should be accorded to the development of technologies which would be meaningful for ecologically and socially handicapped farmers. The World Development Report 1990 on Poverty by the World Bank underlines the continued importance of this emphasis.

Thanks to advances in agricultural production, consumption per capita in the developing world went up by almost 70 percent between 1968 and 1985. However, according to the World Development Report 1990, in spite of impressive achievements in improving both income and consumption, more than one billion people in the developing world are living in poverty. This is the number of people who are struggling to survive on less than $370 a year. The Report rightly stresses that "progress in raising average incomes, however welcome, must not distract attention from this massive and continuing burden of poverty."

Between 50 to 80 percent of the population in developing countries depend on agriculture for their livelihood. Although the contribution of agriculture to GDP is going down in many developing countries as a result of the diversification of the economy, the burden of providing jobs still lies largely with the farm sector. The 1990 report of UNDP on Human Development clearly shows that countries with a low per capita GNP can achieve a low under-5 mortality rate and high life expectancy through placing a high priority on resource allocation for human development, a point which an earlier lecturer in this series, Professor Amartya Sen, has been making for several years. This illustrates the critical role of public policy in rescuing millions of children, women and men from sub-human living conditions. Professor Amartya Sen has often stressed that we cannot reap what we do not sow and that the persistence of chronic hunger is due to the inadequate political attention paid to eliminating it.

The World Bank's 1990 Report on Poverty as well as studies conducted by the International Labour Organization (ILO) indicate that the number of people living in extreme poverty is likely to rise in Africa in the coming years (Table 1). It has hence been appropriate that several of the earlier lectures devoted to the memory of Sir John Crawford have specifically addressed issues in Africa. In this lecture, I wish to consider some of the emerging challenges in agricultural research and public policy as a result of the changing nature of the food security challenge.

Table 1

Number of people living in extreme poverty
(Millions)

	1980	1985	1995 (projection)
Africa	210	278	405
Asia	562	538	450
Western Hemisphere	47	65	58
Total	819	881	913

Source: International Labour Organization (ILO), "High-Level Meeting on Employment and Structural Adjustment," Geneva, 23-25 November 1987, p. 17, cited in Jean Mouly, "Reviving the world's economic growth: chances and risks." Mimeo, February 1989, p. 4.

Food Security Challenges Today

FAO defines *Food Security* as physical and economic access to food to all people at all times. I have been pleading for replacing this concept with that of *Nutrition Security* which involves physical and economic access to balanced diet and safe drinking water to all people at all times. The emphasis on clean drinking water is particularly important in my view. Nutrition Security is essential for giving children an opportunity for the full expression of their innate genetic potential for physical and mental development.

It is now widely accepted that chronic hunger today is due more to the lack of purchasing power than to the non-availability of food in the market. In other words, to win the battle against hunger, we have to fight the "famine" of jobs. An integrated programme of work, wage (ie: the enforcement of minimum wage) and welfare measures in the fields of public health, sanitation, drinking water and education are essential for this purpose.

Compounding the problem of gross economic inequity is the growing damage being done to the ecological foundations of sustainable agriculture. Diminution of the biological potential of soils, loss of biological wealth, deforestation, depletion of ground water resources, pollution, and the growing imbalance between carbon emissions and carbon absorption are leading to a situation where safeguarding the ecological base of agriculture may become the most important food security challenge. It is clear that economic entitlements and ecological obligations must go together for achieving sustainable food and nutrition security.

The Food Security Act of 1985 of the United States is a fine example of an integrated approach to production, conservation and consumption. It would be advisable for every country to adopt similar legislation which can provide the legal framework essential both for sustainable advances in biological productivity and for eliminating chronic hunger. Since the World Bank and CGIAR are deeply concerned with the public policy decisions necessary to stimulate higher production by small farm families based on ecologically sound technologies and to provide increased access to better quality diets for the rural and urban poor, it would be useful to organize a seminar for political leaders and policy makers on the role of legal instruments for the achievement of national goals in food and ecological security. The implications and impact of the US Food Security Act of 1985 could provide the basis for such a discussion.

Technology and Food and Ecological Security

The Green Revolution of the sixties and seventies in wheat and rice resulted in higher production through an improvement in yield per hectare and to that extent helped to save land. India, for example, produced 12 million tonnes of wheat in 1964 from 14 million ha. This was before the advent of high-yielding wheat varieties.

In 1990, Indian farmers harvested about 55 million tonnes of wheat from about 23 million ha. To do this at 1964 yield levels, India would have needed over 40 million ha of additional land. Globally, UNEP estimates that 90 percent of the annual deforestation of about 15 million ha is due to the spread of agriculture. FAO places the estimate even higher — at 17 million ha per year. Thus, the ecological necessity for improving production through higher productivity rather than through area expansion is obvious.

In their article on "Feeding the World in the Nineties" (published in the State of the World — 1990 — Report of the World Watch Institute) Lester Brown and John Young estimate that the world could be losing 14 million additional tonnes of grain output due to land degradation and crop damage caused by factors such as flooding and pollution. According to them, environmental damage could lead to the net gain in global food output remaining at about 1 percent per year, while population growth will be close to 2 percent. They hence conclude that the food supply position will be tight and prices will rise in the coming years.

The position with regard to animal nutrition is equally serious. If under-nutrition or calories deprivation is the major cause of malnutrition in the human population of many developing countries, under-nutrition is even more serious in animal populations. Since grazing land is scarce, the only pathway open for improving the yield of animal products is stall-feeding. The technology of stall-feeding should be based on enriched agricultural raw material and not on food gains. In other words, what we need in population-rich but land-hungry countries is land-saving agriculture and grain-saving animal husbandry.

The needs of land-saving agriculture and grain-saving animal husbandry can be met only by further improvements in technology. At the same time, persistent environmental degradation which is threatening the natural resource base underpinning sustainable advances in biological productivity will have to be arrested. This will call for intensification of efforts in the blending of traditional and frontier technologies in such a manner that the ecological and economic strengths of both are combined. The frontier technologies of particular interest are biotechnology, space technology such as weather satellites and remote sensing, information technology including computer-aided instruction and extension and management technology which helps to introduce a systems approach to all aspects of production, processing, storage and marketing.

A major factor having a bearing on the development and dissemination of new technologies is the nature of the demographic profile of countries in terms of age composition as well as dependence on the primary farm sector for livelihood security. In most developing countries, the population is predominantly young. Over 50 percent of India's current population of about 850 million is below the age of 21. Also, nearly 70 percent of the population derive their livelihood from agriculture and other rural occupations. The future of agriculture in such countries will hence depend on their ability to attract and retain youth in farming and other rural occupations. Otherwise urban slums will multiply and social tensions will grow.

For educated youth to be attracted to work in rural areas, farming and allied rural work must become both economically rewarding and intellectually satisfying. In other words, agriculture should become an occupation which requires brain as much as brawn. Land ownership and tenancy rights and input and output pricing policies should be such that farmers feel encouraged to save and invest surplus funds in strengthening the ecological infrastructure essential for sustainable advances in biological productivity. Since capital is scarce, knowledge must become to the extent possible a substitute for capital. Fortunately, most ecologically sound technologies like integrated pest management and integrated nutrient supply are also knowledge-intensive.

Technology and trade have been prime movers of economic prosperity in the countryside in industrialized countries. Non-farm and off-farm employment opportunities grow when post-harvest technologies and trade opportunities improve. The primary, secondary and tertiary sectors of the economy then get symbiotically inter-linked.

To achieve this goal, we would need a faster rate of agricultural growth. In a recent study of India's development experience conducted for WIDER (World Institute for Development Economics Research, Helsinki) Yoginder Alagh, who was until recently a member of India's Planning Commission, observed, "A high rate of agricultural growth was a pre-condition of faster employment growth. In any employment strategy, anywhere between two-thirds to three-quarters of the desired employment growth would come from achievement of higher agricultural output levels. Thus, widespread agricultural growth was a great equalizer in terms of employment generation and poverty reduction in India."

Nearly half the world's population live in coastal areas. Both the ecological security of coastal regions and the livelihood security of coastal communities need greater attention. There is need for Coastal Systems Research Programmes designed to promote the linked development of capture and culture fisheries, and coastal forestry and agroforestry including the protection of mangroves, coral reefs, sea grasses, and associated flora and fauna. We also need methodologies for an ocean productivity classification on the model of land capability studies. As much carbon is fixed in the ocean as on land and we must derive better benefit from such aquatic carbon fixation.

Inadequate purchasing power in developing countries often leads to uncomfortable food gluts even when there is an increase of only 5 to 10 percent in food grain production. Ironically, in countries characterized by a high incidence of poverty, marketing problems become serious when efforts in increasing agricultural output succeed. Violent undulations between acute scarcity and uncomfortable glut are not uncommon under such conditions. For example, Mary Anne Fitzgerald in an article on hunger in Ethiopia (Financial Times, London, May 5-6, 1990) states, "There are 50,000 tons of grain available in Western and Southern Tigray where the harvest has been good. The Relief Society of Tigray has asked for $18 million to purchase it but so far only $4 million has been pledged." Quite often in Africa, the World Food Programme (WFP) has extended assistance in purchasing locally grown food grains. But for such interventions by WFP, farmers would be cursing themselves for having produced good crops. Imaginative efforts in improving food consumption and in eliminating chronic hunger are essential for accomplishing economically sustainable advances in production.

International cooperation in trade and trade-related matters, in the sharing of environmentally-friendly technologies and in long-term commitments of development assistance to meet the infrastructure and institutional investments required for a more sustainable and equitable agriculture, needs considerable strengthening. All this will call for a revolution, both in patterns of international cooperation and in information systems. Such information systems should be capable of integrating and analyzing the interactions between bio-physical, environmental, economic, social and demographic trends of rural livelihood systems. Unless the substrate requirements for new technologies to strike roots and confer economic and social benefits are clearly understood and attended to, the availability of useful technologies and stagnant production conditions will continue to co-exist.

Response to the Challenges Ahead

By 2020, we may need an annual production of at least 3000 million tonnes of food grains and 200 million tonnes of aquatic products besides larger quantities of vegetables and fruits to provide balanced diets for over 8 billion human beings, many of whom will have enhanced purchasing power. In addition, considerable additional quantities of fuelwood, fodder, fibre and other agricultural commodities will be needed. Even now, fuelwood occupies the second position in relation to the gross value of production in developing countries, as shown below:

Commodity	*Gross Value* (in US $ million)
Rice	70,465
Fuelwood (non-coniferous)	45,769
Sawlogs	44,430
Milk	38,970
Wheat	27,542

(Source: FAO Data 1983-85)

According to FAO statistics, the agricultural self-sufficiency rates of developing countries are likely to drop to 100 percent in the year 2000 from 101 percent in 1983-85. Most of the additional population will be in developing countries and according to a World Bank projection, the proportion of global population living in developing countries in the year 2025 will be 83 percent.

In contrast to the expanding need for food, fuel and other commodities, many developing countries are already confronted with a growing loss of farm land, diminishing resources of water and biological diversity and expanding biotic and abiotic stresses. In addition, all nations may face changes in temperature, precipitation, sea levels and a higher incidence of ultraviolet radiation.

What should be our instruments in handling such a situation? First, we have to tap the untapped technologies on the shelf through appropriate social engineering, extension, and training programmes and public policies in land ownership, input and output pricing and rural infrastructure development. An idea of the extent of opportunities available for taking advantage of existing know-how in rain-fed crops is provided by the data of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) cited in Table 2. Second, we must intensify agricultural research, making effective use of emerging scientific opportunities provided by biotechnology as well as space, information and management technologies. We have to duplicate what has been achieved on the production front during the past 12,000 years in the next 40 years. This cannot be done without the help of new technologies and management tools. Third, we must ensure that ecological sustainability becomes the foundation for all efforts in the development and dissemination of technologies.

Table 2

Grain yields under improved and traditional technologies on deep Vertisols at ICRISAT Center*; Hyderabad, India.

		Grain yield (t ha) Improved systems; double cropping			**Traditional system single crop**	
Year	**Cropping period rainfall (mm)**	**Sorghum/ Maize**	**Sequential chickpea/ intercropped pigeonpea**	**Total**	**Sorghum or**	**Chickpea**
1976/77	708	3.2	0.72	3.92	0.44	0.54
1981/82	1073	3.19	1.05	4.24	0.64	1.05
1986/87	585	4.45	0.38	4.83	0.37	1.27
1988/89	907	4.64	1.23	5.87	0.61	1.18

*Average rainfall for Hyderabad (29 kms away from ICRISAT Center) based on 1901-84 data is 784 mm with a CV 28%.

CGIAR Centers and TAC have been giving serious attention to sustainability issues. I would plead for greater efforts in the following areas:

a) Standardization of measurement tools for (i) disaggregating diverse components of sustainability such as the ecological, the economic and the socio-cultural and (ii) estimating the impact of production techniques on environmental capital stocks such as land, water, genetic diversity and greenhouse gas emission.

b) Selection of participatory research sites characterized by a large extrapolation domain; this is essential for developing location-specific technologies.

c) Organization of demonstration and training centers to explain the implications of adding the prefix "Sustainable" before "farming system". The President of Guyana has offered 400,000 ha of tropical rain forest in his country for developing techniques for the sustainable management of rain forests and a team set up by the Commonwealth Secretariat has prepared proposals for taking advantage of this offer. Such work will need a long-term commitment of financial and technical resources.

d) Diversification of cropping systems and food habits, with particular emphasis on vegetables and fruits; and

e) Promotion of a Sustainable Agriculture Matrix approach on the lines indicated in Table 3. This will call for the integration of considerations of ecology, economics and equity by all concerned with the development of packages of technology, services and public policies.

I realize that existing uni-dimensional structures for policy formulation and task implementation are not conducive to the growth and spread of such a symphonic approach. Often decisions have to be taken on the basis of trade-offs between immediate economic gains and long-term ecological considerations. It will, however, be difficult to make the concept of sustainable agriculture a reality without such coordinated thinking and action.

Table 3

Sustainable Agriculture Matrix
Illustrative components

Basic Principle	Action Points		
	Technology	Services	Public Policy
I. Ecology	Conservation and enrichment of environmental capital stocks	Organization of group activities on a watershed basis	Legal, promotional and educational instruments for the sustainable management of natural resources and for population stabilization
II. Economics	Promotion of biological and farm grown inputs — higher yields at lower cost-diversification of employment and income sources	Organization of input supply and marketing services through farmers' organizations	Incentives for group endeavor and for the adoption of knowledge-intensive farm practices
III. Equity i) Intragenerational	Technology options for resource poor farmers — attention to gender-based occupations	Empowerment of the rural poor through organizational structures designed to take new technologies to the unreached	Steps to protect the livelihood security of the poor through measures in the areas of work, wage and welfare
ii) Intergenerational	Sustainable use of basic agricultural assets	Education and early warning systems	Political commitment to sustainable development

Biotechnology: Opportunities

There has been considerable debate in recent years on the potential impact of new biotechnologies on agriculture. According to Ellen Messer and Peter Heywood ("Trying Technology: neither sure nor soon", Food Policy 15, 336-345, 1990), the impact of biotechnology in overcoming hunger may have to await the next millennium. Since I do not share this view, I wish to discuss a few issues relating to research and extension in the field of biotechnology at some length.

The term biotechnology is currently being used to connote a wide variety of biological manipulations such as cell and tissue culture, embryo transplantation, transfer of DNA material across sexual barriers, microbiological enrichment of cellulosic material, fermentation and various forms of biomass utilization. There are immediate opportunities for the multiplication of superior clones of fruit and forest tree species, as well as plantation crops like cardamom and oil palm through tissue culture methods.

The hard core of biotechnology is recombinant DNA technology resulting in transgenic micro-organisms, plants and animals. The first transgenic plants expressing engineered foreign genes were produced in tobacco in 1983 by the use of *Agrobacterium tumefaciens* vectors. Since then, transgenic material has been produced in a wide range of plants, animals and micro-organisms. The Animal and Plant Health Inspection Service of the U.S. Department of Agriculture issued nearly 100 permits for testing genetically engineered material in the field between November 1987 and September 1990. The plants with new characters now under testing include maize, cotton, soybeans, potato, tomato, tobacco, alfalfa, cucumber, cantaloupe, squash, rice, walnut and poplar. We can expect even more rapid progress in the nineties as a result of the work of research networks like that supported in rice by the Rockefeller Foundation.

The basic research underpinning the techniques of biotechnology has largely been carried out in universities and public-funded laboratories. However, the work on the conversion of scientific information into economically viable technologies has largely been undertaken in the private sector. This had led to the question whether the fruits of such research will be available only to those who can afford to pay adequately for them. For example, in agriculture, some experts have stated that while the "green revolution" technologies arising from research funded by philanthropic foundations like Rockefeller and Ford Foundations and by governments of developing and industrialized countries were available to all farmers who could derive benefit from them, the "gene revolution" technologies associated with biotechnological research may not likewise be available, since they owe their origin by and large to investments made by private companies and may be protected by patent rights. Where should the line be drawn between private profit and public good, particularly in a world characterized by glaring economic inequities?

The results of genetic engineering research in medicine, such as the production of insulin, interferon and different kinds of vaccines, are being disseminated by the pharmaceutical industry. Likewise, applications in animal health care and production can be expected to be spread by private industry. Similar may be the case of enzymes like rennin used for making cheese. In the case of crop improvement, there is an on-going debate about methods of integrating the principles of equity with those of economic profitability. The basic dilemma arises from the fact that while developing nations often represent centres of biological diversity and have rich endowments of biological wealth, the capacity to convert biological diversity into biological productivity through science and technology resides predominantly in industrialized countries, where such conversion work is increasingly in the hands of private industry.

The significance of biotechnology for a better biofuture of the Third World can be illustrated by taking the example of Asian agriculture. Asia has over 50 percent of the global population, over 70 percent of the world's farming families, but only 25 percent of the world's arable land. At the beginning of the 21st century, the per capita land availability will be 0.1 ha. in China and 0.14 ha. in India. The average Asian population growth rate is 1.86 percent.

The only pathway open to countries like China and India for feeding their growing human populations is continuous improvement in yield. This involves research which can further raise the yield ceiling. China has gone into the large scale exploitation of hybrids in rice for this purpose. The tools of biotechnology can help in raising the productivity of major crops through an increase in total dry matter production which can then be partitioned in a way favorable to economic value.

Water availability will be another serious constraint in many developing countries. In several of them the availability of even adequate drinking water is a serious problem. There has been an almost threefold expansion in global irrigated area since 1950 and much of this expansion has been in developing countries. Scope for further expansion is getting gradually reduced. In particular, ground water is already being utilized in an unsustainable manner in several parts of the world. Improved irrigation water management and the incorporation of genes for drought-tolerance in major crop plants are urgent necessities.

In animal husbandry also, the needs of developing nations, particularly in South and Southeast Asia differ from those of the industrialized countries. Most of the productive animals in India, for example, are stall-fed. This enables government to provide farm animals to landless labor families for increasing their household income. Such resource-poor animal-rearing families have to be assisted in running the enterprise as efficiently and economically as possible, by providing services in the areas of genetic improvement, health care, nutrition and marketing. Nutrition has to come from high-yielding fodder legumes and grasses grown in crop rotations and from enriched cellulosic material.

A market research report entitled "Biological Products for Aquaculture-A Worldwide Market Study on Vaccines, Therapeutics, Diagnostics, Hormones and Genetic Minipulations" published recently by the Technology Management

Group, New Haven, U.S.A., suggests that as aquaculture farms increase their production per unit space, effective disease and stress control will assume greater importance. The markets for vaccines, diagnostics, hormones and new feeds will increase. It is anticipated that by the year 2000, 25 percent of world-wide seafood consumption is likely to be produced by aquaculture. Vaccines are seen as a growth area, since vaccines are still needed for many major diseases. In Scandinavia and parts of the U.S.A., nearly all trout and salmon, produced by aquaculture, were vaccinated in 1989 as compared to 5 percent in 1984.

Many companies are developing aquaculture therapeutics to meet the growing demand. It is estimated that over 50 percent of the total global production of fish, shellfish and molluscs is lost to disease. Breeding programmes and genetic engineering have led to the production of new "boneless" breeds of trout that have a better feed conversion rate, and salmon which possess an antifreeze gene to enable them to survive in colder waters. Further research in fish breeding is expected to focus on growth acceleration, sex identification and determination, flesh quality, disease resistance, sea water adaptation, and the ability to utilize specific dietary components. Thus, biotechnological research is opening new windows of opportunity both in terrestrial and aquatic farming systems.

Biotechnology can make a useful contribution for integrating brain and brawn in rural professions. For example, Kerala State in India is planning to develop the district of Ernakulam as a **Biotechnology District,** for taking advantage of its rich educated human resources, particularly educated women, who often tend to be inappropriately employed. The programme will include extensive tissue culture propagation of forest tree species, banana, cardamom and ornamental and medical plants, genetic improvement of cattle and poultry and the establishment of biomass refineries. The cause of educated unemployment is often not the lack of employment opportunities per se, but the paucity of employable skills in educated youth. The prevailing mismatch between

the skills needed for the sustainable conversion of natural endowments into economic wealth should be ended through a carefully planned learning revolution.

Biotechnology and Third World Concerns

A reference needs to be made to a few of the major concerns of Third World scientists and political leaders relating to current global trends in the objectives and organization of biotechnological research. First, the farm sector is a major export-earning enterprise for Third World countries. Therefore, there is genuine concern about the potential adverse impact of genetic engineering research directed at finding substitutes for natural products. Some examples are: high-fructose corn sweetener as a substitute for sugarcane sugar and substitutes for vanilla, cocoa and diosgenin extracted from *Dioscorea* species.

A second major concern relates to the safety aspects of genetic engineering research. Will tests be done in the Third World which are not permitted in the industrialized countries? Will "super weeds" arise from research aimed at the development of pesticide and herbicide resistant crop varieties? Will the ecological groundrules underpinning the field testing of transgenic material be the same everywhere?

Third, the nutritive quality and food safety issues relating to genetically engineered strains and growth promoting agents like bovine growth hormones need careful study, using criteria more relevant to conditions where under-nutrition and malnutrition are widespread. Will crop varieties with multiple resistance to pests contain toxins which will ultimately affect the health of the human beings or animals which consume their economic parts? What kinds of safety evaluation procedures are needed for food ingredients produced by microorganisms, single chemicals and simple chemical procedures and whole foods and other complex mixtures?

Fourthly, will the biotechnology revolution help resource-poor farmers increase productivity largely with the help of farm-grown inputs? How can we design mutually reinforcing packages of technology, services and public policies which can ensure that all rural people — rich or poor, land owners or landless labour families — can derive economic and social benefit from new biotechnologies?

Fifthly, what will be the impact of the extension of intellectual property rights to individual genes and genotypes on the availability of such improved material to developing countries and resource-poor farm families? Also, will intellectual property rights be exclusively reserved for rewarding formal innovations and neglect the pivotal role the informal innovation system has played and is playing in the identification and conservation of plant and animal genetic resources? What are the rights of the farm families who have conserved and selected genetic diversity in contrast to the rights of the breeders who have used them to produce novel genetic combinations? How can the concept of genetic diversity as a common human heritage be promoted, if only a few can derive economic benefit from such a diversity?

Sixthly, will priorities in biotechnology research be solely market-driven or will they also take into consideration the larger interests and the long-term well-being of humankind, whether rich or poor? In other words, will **orphans remain orphans** in the choice of research priorities and investment decisions? For example, rice is the staple of nearly half the human population most of whom live in Asia. Yet, the application of biotechnological know-how to solve some of the important problems in rice production would not have received the financial and scientific support they needed but for the decision of the Rockefeller Foundation to make a major long-term investment in this area.

Finally, there are environmentalists who believe that each technological fix to an ecological problem will ultimately generate new levels of ecological catastrophe. They therefore caution against venturing into unknown territories.

The above concerns can be met only by a proactive analysis of the potential beneficial and adverse impacts of biotechnological research, not only from the economic angle but also from the ecological and equity perspectives. Social scientists and ecologists should be involved in project design teams right from the beginning and should not just come at the end to make a post-mortem analysis. For biotechnology to lead to a better future for human-kind, we need a systems approach, keeping in mind Albert Einstein's exhortation that human well-being should be the ultimate objective of all scientific endeavor.

Several CGIAR centres have integrated the new research tools in their scientific work. UNIDO has sponsored an International Centre for Genetic Engineering and Biotechnology for spreading the benefits of research in this field to Third World countries. Other initiatives of this kind are now in various stages of development. I would suggest that CGIAR should consider organizing, in collaboration with the governments of developing countries, UN organizations, private industries and universities, a network of **Genetic Enhancement Centres** at IARCs and appropriate national research institutes in developing and developed countries for the purpose of evolving breeding material containing new gene combinations. Such material should be readily available for use by practical breeders in the development of location-specific varieties. Location-specific varieties and technologies are essential for achieving ecologically sustainable advances in biological productivity. A global network of Genetic Resource Conservation Centres linked to a similar network of Genetic Enhancement Centres will ensure that genetic diversity is not only conserved but is utilized for the benefit of all. Only such steps can help to bridge the growing gap in economic well-being between nations that have achieved mastery in biological technology and those rich in biological wealth but relatively weak in converting such blessings into economic wealth.

Biodiversity and Biofuture

Our biological future depends on our ability to conserve and utilize the rich genetic diversity occurring in living organisms on our planet. The extent of ignorance on the number of species existing on earth came out clearly at a Conference on the Ecological Foundations of Sustainable Agriculture organized by the Commonwealth Agricultural Bureaux International at London in July 1990. Some experts felt that more than 50 billion species may be occurring, while less than 2 million have been described so far. This underlines the importance of training more biosystematists.

Unfortunately, there is much controversy on methods of saving and sharing the global biological wealth. Discussions on this topic are in progress in various international fora such as FAO and UNEP. The Keystone International Dialogue Series on Plant Genetic Resources has tried to throw light on methods of resolving opposing viewpoints. Terms such as "Farmers' Rights" and "Breeders' Rights" are freely used to indicate the importance of according recognition to the informal innovation system in conjunction with the rights already accorded to plant breeders in the 20 developed nations which have so far adhered to the rules of the International Union for the Protection of New Varieties of Plants (UPOV). The ongoing discussions at the General Agreement on Tariffs and Trade (GATT) on Trade-related Intellectual Property Rights (TRIPs) are also important in the context of North-South relationships in germplasm conservation and exchange. Fourteen developing nations have proposed to the Negotiating group on TRIPs at the Uruguay Round of Multilateral Trade negotiations that plant or animal varieties or essentially biological processes for the production of plants or animals should not be subjected to patent protection.

Farmers and breeders are allies in the common task of advancing biological productivity. Therefore, I feel that their rights should be presented not as mutually antagonistic rights but as mutually reinforcing ones. I would like to suggest that UPOV should evolve into an International Union for the Protection of Breeders' and Farmers' Rights, with its membership including all countries — industrialized and developing.

The UPOV convention is now undergoing revision. A draft revision introduces the concept of "dependence" which would ensure that a variety "essentially derived from another variety protected by PBR cannot be used commercially without the permission of the breeder of the protected variety." It should not be difficult to develop a methodology under the dependency clause which enables recognition and reward for informal innovation. The financial reward in this case will have to go to a special fund which can help to finance conservation and plant breeding activities in the country from which the key genetic material came.

CGIAR institutes have rendered valuable service in the *ex situ* conservation and utilization of plant genetic resources. They can assist in promoting the evolution of a system of recognition which is universally regarded as equitable. A better biofuture for all will depend upon shared goals and action in conserving and using biological diversity.

Food and Jobs

The World Employment Review (1988) published by ILO stated:

"There can be little disagreement that employment is a critical issue around the globe — for young people seeking to establish themselves in a career; for those employed who fear redundancy or redeployment; for employers trying to decide on acquiring new technologies or hiring more workers; for trade unions attempting to protect the security of employment and maintain real wages; for those engaged in precarious work in the informal sector; for older women seeking to re-enter the labor force; for the long term unemployed; for training institutions preparing workers and managers for an uncertain future; for governments trying to manage substantial wage bills and to improve efficiency, and for the self-employed in urban and rural areas who have little in the way of support systems."

Most developing countries facing serious debt burdens and other economic difficulties caused by high prices of petroleum products are unable to provide the support systems essential for encouraging educated youth to take to self-employment. Much, however, can be done to enhance returns from scarce resources through synergy among diverse programmes connected with rural development. A consultation convened by the International Fund for Agricultural Development (IFAD) in 1988 suggested that the ongoing Farming Systems Research (FSR) Programme could be developed, where appropriate, into a Rural Systems Research Programme (RSR), specifically for the purpose of achieving a diversification of employment opportunities in rural areas. The essential features of a RSR programme will be the following:

a) The programme should foster the following three groups of linkages:

   i) Backward linkages with modern science and technology, particularly biotechnology, space technology and computer sciences

   ii) Forward linkages with markets, agro-industries and the services sector, and

   iii) Lateral linkages among crops, farm animals, fisheries, forestry and rural industries;

b) While fostering such linkages, emphasis should be, on the one hand, on ecologically sound technologies, and on the other, on strengthening growth linkages among the primary (farm), secondary (industries) and tertiary (services) sectors of the rural economy. Traditional technologies should be preserved, whenever they are still the best from the ecological and employment-generation points of view. They should be enriched and their economic viability and consumer acceptance enhanced by suitably blending them with frontier technologies;

c) The RSR programme should be designed and implemented jointly by scientists, the village community, non-governmental organizations and input supply and marketing agencies. Research on delivery systems should receive adequate attention;

d) Social scientists should be involved right from the planning stage, so that they are able to play a proactive rather than a reactive role;

e) A new approach should be developed to component technology development by starting with the priority problems confronting small farmers and working towards scientific approaches and solutions. Priority should go to activities which can lead to the sustainable enhancement of the quality of life of the rural poor; and

f) The RSR Programme should include specific attention to the training of women in new skills. The training methodology should be "learning by doing." A well planned RSR programme will help to give concurrent attention to the production of more food as well as the generation of more jobs and income.

Research for Tomorrow

Sir John Crawford advocated anticipatory research where new problems or new opportunities may arise. To him, today's economic progress should not be at the expense of tomorrow's prospects for similar advances. The Second World Climate Conference is currently in progress at Geneva, Switzerland. At this conference strategies for avoidance and adaptation in relation to potential changes in global climate are being discussed. Until now, we were more concerned with a study of the impact of climate on human activity. A matter of equal concern now is the impact of human activity on climate. The international research networks operated by IRRI, CIMMYT and other international centers provide insights into genotype x environment interactions across the globe. CGIAR can take the lead in organizing, in collaboration with WMO, UNEP, FAO, UNDP, IBRD and other interested organizations an *International Research Network on Climate Change and Food Security* with the following aims.

a) Estimation and monitoring of the emission of greenhouse gases as a result of farm operations under different agro-ecological and technological conditions.

b) Standardization of techniques both for minimizing agriculture's contributions to the accumulation of greenhouse gases and for withstanding additional biotic and abiotic stresses on crops and farm animals arising from climate change.

c) Promotion of research and training in the field of restoration ecology, in the afforestation of degraded forests and in the sustainable management of tropical rain forests.

d) Anticipatory research and development measures in coastal areas to avoid or minimize the adverse impact of potential changes in sea levels.

e) Standardization of methods for deriving benefit from higher CO_2 concentration in the stratosphere.

f) Standardization of post-harvest technologies for perishable agricultural commodities based on non-CFC dependent refrigeration methods, and

g) Stimulating policy research designed to strengthen the public policy back-up both for avoiding adverse changes in climate and for adapting to new growing conditions.

This will be another example of the pathway of sustainable dynamism in agricultural research which Sir John Crawford wanted CGIAR to nurture.

I thank you again for this opportunity to pay homage to the memory of one of the greatest scholars and humanists of our time.

*Printed on recycled paper.