Towards 2010:

Challenges for Agriculture and Agricultural Research

Conclusions of an informal consultation organized by the International Service for National Agricultural Research, The Hague, May 23-25, 1991

The International Service for National Agricultural Research (ISNAR) began operating at its headquarters in The Hague, the Netherlands, on September 1, 1980. It was established by the Consultative Group on International Agricultural Research (CGIAR), on the basis of recommendations from an international task force, for the purpose of assisting governments of developing countries to strengthen their agricultural research. It is a nonprofit autonomous agency, international in character, and nonpolitical in management, staffing, and operations.

Of the 16 centers in the CGIAR network, ISNAR is the only one that focuses primarily on national agricultural research issues. It provides advice to governments, upon request, on research policy, organization, and management issues, thus complementing the activities of other assistance agencies.

ISNAR has active advisory service, research, and training programs.

ISNAR is supported by a number of the members of CGIAR, an informal group of donors that includes countries, development banks, international organizations, and foundations.

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INTERNATIONAL SERVICE FOR NATIONAL AGRICULTURAL RESEARCH

1991

Citation

ISNAR. 1991. Towards 2010: Challenges for Agriculture and Agricultural Research. The Hague: International Service for National Agricultural Research

AGROVOC Descriptors

agriculture; policies; research

CABI Descriptors

agricultural research; policy; research

Foreword

At the beginning of the last decade, the Consultative Group for International Agricultural Research (CGIAR) founded the International Service for National Agricultural Research (ISNAR) and entrusted it with the specific mandate of strengthening national agricultural research systems (NARS). There seems to be no need to change the original mandate at the present time. However, at all times, NARS are facing new challenges and must deal with emerging issues if agriculture is to succeed in meeting the requirements for healthy economic development and vital resource conservation under conditions of constantly increasing population growth. The expectations of policymakers, consumers, and farmers for the future roles of agriculture must be identified in order to determine the likely tasks of agricultural research. Such forward looking is a precondition of the development of a viable strategy for ISNAR, to ensure that it can participate actively and successfully in institution-building activities for the benefit of agricultural research systems.

In the process of reviewing and revising the existing strategy, ISNAR invited a small group of knowledgeable and concerned professionals to attend group discussions, in order to gain from their experience and vision. The major results of our consultation are recorded in this brief document and will also be reflected in ISNAR's new strategy. Our sincere thanks go to all participants for sharing their concerns with us. Although there were no conclusions drawn, the views on some of the major challenges and likely developments of the future deserve wide distribution. Declan Walton's special contribution as the author of this summary document is gratefully acknowledged.

The Hague, May 1991

Christian Bonte-Friedheim
Director General

Introduction

ISNAR is currently reviewing its long-term strategy, established in 1986. As part of this process, it is holding a series of formal and informal consultations with a wide range of outside interests. On 23–25 May 1991, it organized a small informal consultation, in brainstorming mode, on the challenges that appear likely to be facing agriculture and agricultural research in developing countries over the next twenty years or so. These challenges can be expected to determine the tasks facing national agricultural research systems (NARS) in developing countries around the world. The needs of the NARS will in turn affect the types of service for which they look to ISNAR. The subject-matter of the consultation was thus the broad context within which ISNAR and its national partners are likely to find themselves working over the longer term and the emerging issues that they are likely to confront.

The individuals invited to participate in the consultation came from a broad range of backgrounds. Their names are given in annex I. An approximately equal number of ISNAR staff members also participated. The present report is not a chronological summary of the discussions, but rather an attempt to draw some conclusions from them for the benefit of ISNAR and its strategy making. The conclusions are ISNAR's own; although intended to be faithful to the discussions, they have not been specifically endorsed by the invited participants. The report incorporates some additional background material on points that were made during the consultation. The main emphasis throughout is on crops, corresponding to the expertise of the participants; livestock and other sectors are given less attention.

Gazing into the crystal ball can be an exercise in narcissism: we see the reflection of our own anxieties and convictions, rather than the course of events to come. It must therefore be underlined that we are not attempting to foretell the future, but simply to make the most intelligent guess that is possible in May 1991 at the forces that will be shaping the agricultural and research environment of developing countries during the next two decades.

The Economic, Social, and Environmental Framework

Population

The trend is for a gentle decline in the high rate of population growth in developing countries. Looking at the figures for all developing countries together, the last three decades show the following picture:

From 1961–70 the rate of expansion was 2.5% per annum.
From 1971–80 the rate of expansion was 2.2% per annum.
From 1981–90 the rate of expansion was 2.1% per annum.

Overall, the most reasonable assumption is that the trend will continue. During the twenty years up to 2010, the population of the developing countries might increase by about two billion, bringing it up to more than eighty percent of the world total.

The one major exception to the general pattern is sub-Saharan Africa, with less than ten percent of the world's population but more than a fair share of the world's problems. This is the only region for which the demographers predict accelerating growth in the nineties. Fertility rates remain high, while infant and child mortality rates (which are also still very high) continue to drop. However, several countries in Africa south of the Sahara appear to face the likelihood of a major disruption in population growth over the next one or two decades as a result of AIDS (and to a lesser extent malaria, water-borne diseases, and other health hazards). The peril confronts both rural and urban people, highly trained cadres as well as a significant proportion of the labor force. It must be intensely hoped that medical progress will prevent this dire threat from becoming a reality.

The Rural-Urban Balance

The rate of urban growth, from both natural increase and rural out-migration, is tending to accelerate. For the developing countries as a group, urban populations expanded at an annual rate of 3.64% in the sixties, 3.90% in the seventies, and 4.73% in the eighties. Here again, there is no evident reason why the trend should change.

The food needs of the cities will be rising at extraordinarily high rates. If urban growth hits five percent per annum, urban food supplies will need to double every fourteen years, merely to keep pace with the increase in numbers. In fact, urban demands for food can be expected to increase even more rapidly, under the impact of (hopefully) rising levels of nutrition and changing patterns of consumption.

The need for food that is convenient to prepare and consume has been the single most important driving force behind the move away from traditional staples and towards wheat, maize, and to some extent, rice. Accelerating urban growth will make the pressure for these foods still more intense. ***Increased convenience in the use of traditional crops will have to be a very important target for research in plant breeding and post-harvest technology.***

There are very large regional variations in the balance between town and country. In Latin America, urban populations now represent more than seventy percent of the total. In Asia, they are less than one-third. The difference in patterns can be seen by comparing two countries with participants in the consultation, Brazil and India.

Brazilian policies have been oriented mainly toward urban development. Despite a still high rate of overall population growth, the numbers in rural areas have been going down in absolute terms. During the eighties, the rural population of Brazil fell by 0.84% per annum. The situation is very different in India. Rural populations rose during the eighties by 1.62% per annum. Indeed, more than half of the country's population increase during the decade took place in rural areas, where land is already a scarce commodity.

Within Asia, we can expect to see two rather different models of development shaping up. Countries like India, that do not at the moment have large-scale alternatives to offer rural populations, are likely to undergo increasing pressure on already small land-holdings, as well as the emergence of growing numbers of landless. Countries that can offer significant opportunities for employment in the industrial or services sectors (such as Malaysia) foresee a gradual increase in the size of farms and the development of a dualistic agriculture with a growing number of commercial enterprises.

The different patterns of change in the rural-urban balance must have far-reaching effects on the way policymakers look at many problems, such as employment in rural areas, land tenure and farm size, the choice of agricultural technology (including mechanization), and options for agricultural growth. NARS that are coping with different situations are likely to have research objectives that differ on important points.

The challenge facing policymakers (and researchers) in the densely populated countries of South Asia, the hub of world poverty, should not be underestimated. They must devise technologies that will make remaining on the farm attractive to young people, and that will enable underprivileged farmers to increase their productivity — the only road to increasing farm incomes — in both higher-potential and marginal areas. They must seek expanded opportunities off-farm for rural populations to earn money. They must prevent underprivileged consumers, whether urban or rural, from being sucked into a downward spiral of poverty, malnutrition, and disease — by launching intervention programs to provide work, wages, and welfare, for instance, or to provide clean drinking water and better nutrition. ***Above all, a historically unprecedented rate of increase in food production must be maintained, for at least the period covered by our time horizon, even when the easier options for growth are used up.***

In all developing regions, government policies should give a very high priority to rural education. This will prepare the coming generations to either absorb increasingly sophisticated technology in agriculture or to find employment in the cities.

Production and Trade of Cereals

In order to assess the pressures that will be placed on national production systems, it is necessary to take a look at possible trade patterns. The problem may be expressed in a grossly oversimplified way in terms of cereals. On a conservative estimate, the developing countries are going to need, by the year 2010, an extra half billion tons of cereals a year. Where are these cereals going to be grown, and by whom?

There is, of course, no single answer. Some developing countries will be — or already are — sufficiently prosperous that they have the option of producing or importing the additional food they need. In this case, their decision will be influenced by political considerations (e.g., the extent to which they are ready to be dependent on foreign producers for their basic foods), as well as by economic factors and social requirements (particularly rural employment). The issue of convenience for consumers, mentioned above, will obviously have a major effect.

Other developing countries will not be in a sufficiently strong economic position to make a free decision on the domestic production or importation of basic foodstuffs. ***Without reasonably buoyant foreign exchange earnings, most developing countries will have no alternative to maximizing their domestic food production.***

Prospects are likely to be greatly influenced by the outcome of the current Uruguay Round of Multilateral Trade Negotiations in GATT. It is possible that within the framework of the GATT Round, the developed countries will move toward decisive changes in their agricultural policies. These are likely to cause surpluses to disappear and international prices to rise, at least for a time. Another possible scenario would see the emergence of major regional trading blocs, rather than a global accord; interregional competition would presumably keep international prices low. A third possibility would be a series of relatively minor adjustments, without any resolution of the distortions that underlie agricultural trade. The outcome is impossible to predict at the present time. The only certainty is a continuing period of uncertainty.

At present, the developing countries produce about ninety percent of their cereal requirements, in total. The ratio is tending to decline slowly, with imports playing a relatively larger role as the years go by. It would seem hazardous to predict a major change in this trend, although we must recognize the possibility of this happening. As a guess, it might be assumed that in the year 2010 between eighty percent and ninety percent of the cereal requirements of developing countries will still be produced domestically. ***Africa is projected to face a relatively rapid increase in cereal imports.***

The easier ways of increasing production are running out of steam. The rate at which additional land is brought into cultivation is falling rapidly: the rate of increase in the arable area of developing countries was halved between the seventies and the eighties (from 0.58% per annum to 0.26%). The rate of expansion of irrigated areas is also dropping fast, going from 2.22% per annum in the seventies to 1.19% in the eighties.

At the same time, environmental stresses (examined below) are building up, causing losses of productivity and even of arable land.

In terms of cereals, everything leads to the conclusion that the pressure on national production systems in developing countries will in most cases remain high over the next twenty years. Agriculture will, even more than it is at present, be technology-driven. ***With yield increases becoming more difficult to achieve as the easy options run out, agricultural research will have to make a still larger contribution to progress in the future.***

Prospects for Agricultural Exports

Prospects for the agricultural export earnings of developing countries can at best be described as mixed. Traditional exports to industrialized countries face a stagnant market. Many developing countries have had spectacular successes with the development of niche markets. These, however, have a tendency to get crowded as competition builds up. And, although this competition tends to lower prices, in turn boosting the rate of market expansion, in general there is a danger that export earnings may be quickly eroded.

The most promising area for exports appears to be trade among the developing countries themselves, based on regional complementarities. However, the extent to which political harmony can open avenues of trade and genuine cooperation can be built up in various regional groupings remains to be seen. The outcome of the Uruguay Round can have a significant influence. Independent of government policies, there is a trend towards more, informal, cooperation and trade across frontiers, and this may become a significant factor in some regions.

In an international environment that is increasingly competitive, countries will be seeking to develop new exports and to substitute for imports. For the promotion of exports, direct subsidies may be discouraged or banned in the future. Investing in research can be considered as a more respectable alternative. Technology is also likely to play a major role in achieving import substitution, as crops are adapted to new ecological conditions. ***Thus, national research systems, particularly in the middle-income countries, are likely to remain under pressure in the trade context to produce a continuous stream of new or improved technologies.*** Although in the case of research for new market niches, this pressure may favor private-sector research because of the more rapid response times in the private sector.

Economic Progress and Economic Adversity

The eighties have yielded a very checkered record for the economic performance of developing countries. For many, it has been a most unhappy period. Per capita gross domestic product (GDP) has declined in sub-Saharan Africa and, to a lesser extent, in Latin America and the Caribbean. On the other hand, outstanding growth rates have been achieved in East Asia. Details of past performance by region and a forecast for the nineties have been advanced by the World Bank in "World Development Report 1990" (table 1).

Table 1. Prospects for the 1990s

	Real GDP Growth Rates			Real GDP per Capita Growth Rates		
	Trend	Recent experience	Forecast	Trend	Recent experience	Forecast
Group and region	1965-80	1980-89	1989-2000	1965-80	1980-89	1989-2000
Industrial countries	3.7	3.0	3.09	2.8	2.5	2.6
Developing countries	5.9	4.3	5.1	3.4	2.3	3.2
Sub-Saharan Africa	5.2	1.0	3.7	2.0	–2.2	0.5
East Asia	7.3	8.4	6.6	4.8	6.7	5.1
China	6.4	10.1	6.8	4.1	8.7	5.4
Other	8.1	6.4	6.3	5.5	4.2	4.6
South Asia	3.6	5.5	5.1	1.2	3.2	3.2
India	3.6	5.6	5.2	1.2	3.5	3.4
Other	3.9	5.0	4.8	1.2	2.2	2.4
Eastern Europe	5.3[a]	1.4[a]	1.9	4.5[a]	0.8[a]	1.5
Middle East, North Africa, and other Europe	6.3	2.9	4.3	3.9	0.8	2.1
Latin America and the Caribbean	6.0	1.6	4.2	3.4	–0.6	2.3

Source: World Bank. 1990. World Development Report 1990. Oxford: Oxford University Press.
a. Estimates.

It is notable that the Bank forecasts positive rates of per capita growth for all regions between 1989 and the year 2000. Somewhat less optimistic figures have been advanced by the United Nations.

Under the onslaught of economic adversity, many national systems of agricultural research, especially in Africa, have been starved of funds and have gone into decline. Has the worst now passed? One can be hopeful about prospects for debt-forgiveness, which will free the most vulnerable countries of a heavy burden. But the outlook for terms of trade is much less encouraging. And of course, ***political stability is an indispensable condition for getting back into the high-performance league in agriculture or any other sector.***

Looking at the total picture, ***we expect the next ten years to see rapid progress in those national research systems that have already forged ahead in the eighties.*** Systems that have been stagnating or in disarray can be expected to recover, but their new advance may be slow for the first few years. We have already seen a wide range of levels of development and capacity among the NARS; over the next ten years the disparities may widen still further.

Environmental Stresses

Pressures on soil and water resources in the next twenty years seem bound to multiply. Soils are already being degraded over vast areas of the tropics by unsound agricultural production practices. At the same time, good agricultural land is being lost as a result of urbanization, road-building, and other developments. Population pressures will push crop production into marginal lands, not just drier areas but also saline, acid, peat, and degraded lands. ***The pursuit of a fully sustainable agriculture will involve new initiatives, new practices, and new costs.***

The processes involved in the loss of tropical soils are still only partially understood. Strategic research is still needed, and this is a subject for the international agenda. Few national systems at present have the capacity to carry out research of this type.

Similarly, the rehabilitation of degraded soils is a subject requiring further research. Not enough is known about needs, potentials, technologies, costs, and benefits. In the coming decades this will certainly be important locally and may well become so globally.

The most important agent for soil conservation is the farmer. Soil conservation offers long-term benefits, but it also involves short-term costs. Farmers are most unlikely to adopt soil-conserving measures unless they can recover their costs and make a profit in the short term; farm prices must provide an incentive for soil conservation, complemented by appropriate regulatory measures and social mechanisms. Furthermore, farm people are themselves an integral part of their environment: ***education and training of farmers can enable them to absorb relatively complex, system-based techniques of conservation. Investment in human capital may be the most cost-effective way of saving an ecosystem.***

The problems of rural energy are still far from solved. Fuelwood remains the principal source of household energy for nearly three billion people in developing countries, and cheap alternatives are not yet in sight. Among nonconventional sources, there may be some prospects for photovoltaic cells using solar energy, but efficiencies have to rise and prices fall before this becomes more than a hope. In the meantime, manure that should go into the ground goes up in smoke; trees and shrubs that should protect the soil are cut and burned.

Forests may have to be sacrificed, as they have been sacrificed in most of the industrialized world, to provide land for agriculture or for other purposes. But this should be done in a rational, planned manner. Forests as a valuable natural resource are unfortunately being squandered in all developing regions. The rate of deforestation rose substantially between the seventies and the eighties, and it is believed to amount now to about 17 million hectares per annum. Current estimates show subsistence farmers as responsible for more than sixty percent of the annual loss. Other direct causes are overgrazing, fuelwood gathering, commercial logging, and the development of infrastructure and industries. Underlying these direct causes, however, are the main culprits, of which poverty is the chief.

The best cure for deforestation, as for so much else, is development. Increasingly, politicians, planners, and scientists will have to tackle a nexus of interconnected problems relating to population, poverty, agriculture, forestry, energy, and the environment.

The conceptual and institutional difficulties of this approach are daunting. For instance, there is no way at present in which the off-farm costs of unsound agricultural practices (such as the silting of dams by eroded farmland) can be reflected in prices.

While soils attract the most attention, it is possible that by 2010 water may be the key constraint in many areas. For increasing agricultural production in rainfed zones, a major challenge will be to make effective use of the rainwater that becomes available. Irrigated agriculture will face different problems in different areas, but the overall picture is likely to be increased competition for limited supplies of water. In the case of irrigation from groundwater, supplies may be threatened as the water table falls. Chinese researchers are already taking productivity per unit of water (as distinct from productivity per unit of land, labor, or time) as a research objective. This approach may have to be widely adopted. ***The recycling of irrigation water is a specific research subject that was suggested at our consultation.***

The maintenance of biodiversity will also remain a key concern. As a result of greatly stepped-up efforts over the last few years, the plant gene banks are bursting, and scientists have enough work to keep them busy at least until 2010. However, erosion of the planet's genetic resources is still continuing. The level of international action to conserve plant diversity must be at least maintained, and preferably intensified. The situation of animal genetic resources, especially domesticated animals, is more disturbing. Relatively, much less has been done and a far higher proportion of the original genetic capital has already been lost.

The danger of climate change may determine the research agenda in fifty years' time, but it is considered unlikely to do so in twenty. There are, nevertheless, certain research areas that may be given additional prominence in the short to medium term because they address both climatic considerations and the wider requirements of agricultural productivity. These include the reduction of greenhouse-gas emissions from rice, by improving the use of mineral fertilizers, and from livestock production, by improving livestock feeding practices.

Developing countries will be obliged to give increasing prominence to environmental issues for three reasons:

- ***the emergence of serious physical problems in their natural resource base,*** such as soil erosion or water shortages;
- ***domestic concern about the environment;***
- ***the transmission, via aid programs, of concerns about the conservation of natural resources*** that have surfaced in donor countries.

The third of these may have the most impact over the next few years. However, the matter must be viewed in perspective. Even in the most highly industrialized countries, where environmental concerns have to be taken fully into account, they are a significant factor in determining the research agenda but not the major one. And ***the progress of developing nations must not be shackled by norms from the industrialized world which the richer countries did not have to face at a comparable stage of their development, and which yield more costs than benefits*** in the reality of the poorer nations today.

Higher-Potential and Lower-Potential Areas

For decades, policymakers have wrestled with an old dilemma: How far should efforts and resources be targeted towards high-potential areas (where they will give the largest increase in production) and how far towards areas of relatively low potential but with high populations (where their impact will be greater in terms of social justice, such as raising the income and nutrition levels of the poor)? There do not appear to be developments now on the horizon that are likely to bring about basic changes in this issue.

If, as we expect, most developing countries continue to produce the greater part of their staple food requirements at home, while at the same time seeking to step up their agricultural exports, they will be aiming at high growth rates in both production and productivity. The burden is bound to fall first on the areas of high potential. Depending on the circumstances of individual countries, considerable attention may also have to be paid to less-favored areas for several possible reasons: their contribution to the market, the classic reasons of social justice, and the safeguarding of ecosystems that may be particularly fragile.

The development of new technologies for rainfed areas will certainly become a major line of research over the longer term. For instance modern biotechnology (dealt with further below) opens up at least a theoretical possibility of improving the drought resistance of traditional crops by genetic enhancement. New types of tree crops for areas of fragile soil might also be developed. Even without looking so far ahead, in countries where the rural population is high and growing, technology is likely to be increasingly slanted towards rainfed areas, partly in order to avoid massive population shifts to either the cities or the more favored rural zones.

The precise challenge of the next two decades, in brief, will vary from country to country. Some will be lucky enough to have options: they can decide how much effort will go into the higher-potential areas and how much production will come out of the more fragile rainfed areas. Others will have no choice. Production imperatives will oblige them to make the most of all their natural resources, whether of higher or lower potential.

Countries and peoples of all regions will have to accustom themselves to the idea of stewardship, of maintaining intact for future generations the resources that they have inherited. They will have to recognize also that while the dangers to fragile ecosystems are more obvious, those to areas of higher potential pose a greater threat to production in the future.

Research Challenges and Responses

Directions for Research: The Systems Approach

Technologies for the nineties and beyond can be envisaged as resting on four pillars:

- ***ecological sustainability;***
- ***economic efficiency;***
- ***equity in terms of social groups, gender, farm size, and generations;***
- ***participatory research.***

This was referred to in the consultation as the "future paradigm."

Issues relating to sustainability have been analyzed above. The challenge for the future is to develop ecologically sound technologies that carry a minimum cost penalty and can be applied without creating unnecessarily complex systems. A certain degree of complexity will be unavoidable. The Green Revolution was relatively simple: provided that improved seeds, water, and other inputs were available, it depended on the decisions of individual farmers. Relatively little communal action was required. The newer approaches, on the other hand, particularly with regard to environmental dangers, often require collective decisions and joint action by a rural community. They will be more difficult to explain, and adoption may not be carried out with such easy enthusiasm as was the case with Green Revolution technologies. The bright side is that farmers will rarely (if ever) reject a technology that is clearly risk-reducing and profit-enhancing. Ecological and economic criteria go hand in hand.

Systems approaches were constantly advocated in the late seventies and eighties. Cropping systems, farming systems, resource management systems — the tendency has been to broaden the approach as difficulties and disappointments emerged. There are sceptics, but the balance of opinion remains that agricultural research has no alternative to moving in two directions simultaneously: towards the molecule and towards the system. Current thinking in some quarters advocates looking at "rural systems" as the basic macro-approach, while keeping the farmer and his problems in the foreground.

The rural systems approach can be particularly important in a subject like agroforestry. Whether the primary concern is to meet fuelwood needs, to improve farming systems, or to rehabilitate degraded land, experience has shown that local populations generally prefer multipurpose trees, are reluctant to commit a large part of their labor to such projects, and will only accept

projects that are compatible with their values and traditions. Rural systems research can be necessary to prepare the way.

The system can be the basic unit for the diagnosis of problems, the planning of research, and the integration of separate technologies. But this does not mean that everything has to be done in convoy, with the rate of progress limited by the speed of the slowest ship. Managing systems-based research can be a form of art: the art of combining and integrating different lines of research carried out separately, each in its own way. And ***managers must keep an eye on the farmer; they must not get carried away by the beauty of technology as an end in itself.***

Directions of Research: Modern Biotechnology

Biotechnology can be represented as a gradient of technologies, starting at a relatively simple level with tissue culture and rising sharply through recombinant DNA to the genetic engineering of plants, animals, and microorganisms (figure 1). Plant breeders have based their work on biotechnology since they adopted the principles of genetics, first outlined by Mendel in 1866. ***New techniques, based on recombinant DNA technology, monoclonal antibodies, and novel methods of cell and tissue culture, which are arousing such widespread interest today, should be labelled "modern biotechnology."***

There is no debate over whether developing countries should start moving up the gradient: the more richly endowed national systems are already well on the

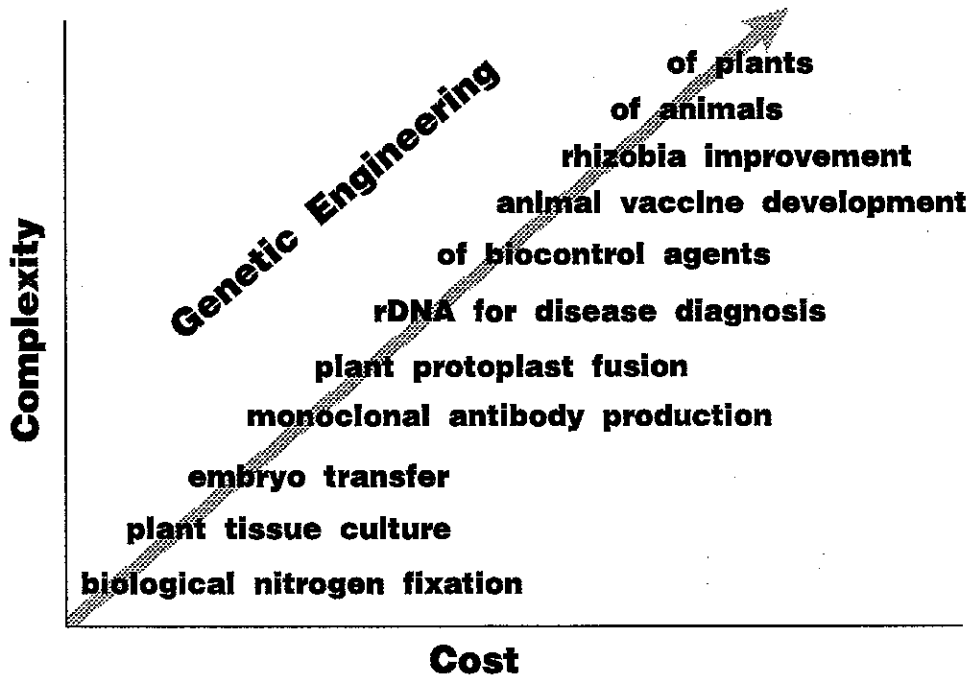

Figure 1. Classifying biotechnologies

way. Even the smallest and poorest should be thinking about a "survival kit" based on modern techniques. For instance, a country where root crops are a staple food could profitably invest in a tissue-culture laboratory. At a capital cost of about $20,000, this would permit the importation in tissue culture of virus-free clones developed in research stations abroad, and their rapid multiplication if they prove adaptable to local conditions and acceptable to producers and consumers.

Further up the gradient, the issue for decision is how far a national system should develop its own in-country capacity in modern biotechnology, and how far it should rely on access to outside institutions. This will to some extent be a political matter. If the main concern is for export crops, countries may well be influenced by the atmosphere of high international competition for markets, and go for the maximum in-country capacity they can afford. They will, however, have to bear in mind that the costs of the new techniques are falling continuously as new methods and new machines are devised; they will need to take precautions against locking themselves into a highly expensive approach that may become obsolete within a very few years.

Paradoxically, the development of biotechnology will increase the load on traditional plant breeding programs. Only the breeders can effectively test the new varieties that may emerge from the laboratories. Indeed, the existence of a traditional plant breeding program is an absolute condition for a successful move up the gradient of biotechnology in the area of crop production.

Current technology can modify a single gene on a chromosome. Major breakthroughs will require more complex transfers. For instance, transferring the ability to fix atmospheric nitrogen to cereals (and thus limiting the need for nitrogenous fertilizer) involves at least six genes. ***Longer-term progress will depend on further advances in basic science, notably in such areas as the mapping of genomes.*** Among possible research objectives, priority might be given to efforts to increase the total biomass of a given crop, and at the same time to improve the partitioning between food and nonfood components.

Patents are now granted in some countries belonging to the Organization for Economic Cooperation and Development (OECD), notably the USA, for genetically manipulated plants, animals, microorganisms, and related biotechnology processes. In the OECD countries as a whole, about half of the work on modern biotechnology is being done in the private sector. The question of access to new technology on the part of developing nations is thus a highly important one. National legislation on intellectual property rights can be necessary for access to patented technology held abroad, as well as for protecting the commercial value of discoveries made at home. In negotiating access, a developing country will need to be well informed or well advised. It should also have a clear idea of who, initially and ultimately, is going to pay for commercially acquired technology.

Concerns about biosafety are high on the international agenda. No country will wish to enter the field of recombinant DNA without having in place adequate mechanisms for ensuring the safe release of genetically modified organisms.

Considerable experience is accumulating in risk assessment, and it can be drawn upon by new national systems.

There is also concern to ensure that the end results of modern biotechnology are socially benign. The Green Revolution was accused incorrectly of indifference to the fate of small farmers, and it will be necessary to undertake proactive social research from the earliest phases to avoid the same charges being levelled again. Bringing biotechnology to bear on "orphan commodities" that are important to small farmers as either food or cash crops is one way in which benefits could reach those most in need of them, although this will require major institutional changes in how science supports such developments.

Opinions are divided on whether modern biotechnology should be the subject of a specialized institution or slotted into existing research organizations. Clearly, it is a set of new tools for research, rather than a new discipline. In most instances, integration of the new techniques into the existing NARS and university research programs will have the most beneficial, long-term effects on the development of science within a country. At the same time, it involves policies (on property rights, biosafety, etc.) that fall outside agriculture. For this reason, there is a powerful case for creating a national committee or commission to bring together the various sectors concerned in order to develop a national policy on the application of biotechnology to agriculture.

At the international level, there is little support for the idea of a single center specialized in biotechnology. On the other hand, there may be some scope for groups of developing countries to pool their efforts, either in the negotiation of access to commercial technology or in the support of highly sophisticated and expensive research that they could not afford separately.

How far will the new techniques be translated, over the next twenty years, into actual yield increases in farmers' fields? This is a question to which only the most tentative answer can be given.

Progress will obviously depend, in the first place, on the ability of scientists to produce results. Practical impacts in such areas as diagnostic tools and vaccines can already be seen, and this is likely to strengthen over the shorter term. ***More far-reaching progress in gene enhancement could arrive within a decade and could have a major impact on the production figures between ten and twenty years hence.*** It seems likely that new technology will, for certain commodities, reduce the length of the "product cycle" in agriculture, just as it has in industry. More rapid methods of testing, reproducing, and diffusing new varieties, new vaccines, or new types of inputs should permit their widespread use much more quickly than we have hitherto seen. Extension to farmers should be no problem if the new product offers a truly significant increase in profitability. Progress could thus be rapid, once new technologies have been developed.

One needs to recall, however, that we are dealing with two variables: the rate of progress in basic science and the rate at which discoveries can be translated into widely usable technologies. Peering into the future beyond the next five years yields speculations, not predictions. Caution must be the watchword.

Lowering the Cost of Production

A constant theme of the consultation was the need to raise efficiency and lower costs in production. To some extent, we are talking about substituting knowledge for physical inputs in what might be called high-technology, low-input systems. The archetype of this approach is integrated pest management. The overall aim is to maintain yields while reducing purchased inputs. This cuts the economic risk faced by small farmers, allows them to increase their profit if prices remain stable, and lessens the long-term danger of soil and water pollution. For export crops, a lowering of production costs equals an increase in competitiveness.

Several specific suggestions were advanced for research that could contribute, directly or indirectly, towards this objective. For instance, the use of electronic sensors for triggering off irrigation, pesticide sprays, or other interventions could hold promise even outside commercial farms as prices drop. ***Weed control was felt to be an underresearched area, in which significant new progress could have a great impact.***

Improved medium- and longer-term weather forecasting could be of great potential importance for farmers in rainfed areas. Reasonably accurate predictions of the starting date and duration of the rainy season could avoid false starts and help make the best use of available rainfall. A good deal of work is already being done in this area and progress is badly needed.

Research should deal with the total biomass of a given crop, not just with the commodity portion. There are many potential uses for the nonfood components, not the least of them being livestock feed, and in the last resort what has hitherto been treated as waste can perhaps be recycled through a "bio-refinery" as mulch.

Putting It All Together

At the National Level

As of May 1991, we have not been able to identify incipient major trends that will alter the face of world agriculture or the problems of developing nations. Developments in the global trading system may give countries a freer choice between importing and producing the basic foods they need, but fear of reliance on external food sources is deeply ingrained in human nature, and we doubt whether there will be a sudden massive drop in self-sufficiency ratios. With population growth slowing but urbanization accelerating, domestic food markets will continue to grow rapidly, and increases in domestic production will have to come mainly from improvements in yields. Environmental stresses will continue to build up remorselessly, even in high-potential areas, unless they are tackled resolutely. ***Science-based agriculture will be the name of the game. Modern biotechnology offers new tools and has vast long-term potential, but it holds no magic shortcuts.***

The NARS will thus remain under pressure to deliver a constant flow of new technologies. However, we expect the differences between national systems to widen still further in the period ahead. There will be differences in capacity and sophistication, reflecting variations in national wealth, resource endowment, country size, institutional development, and the degree of importance attached to agriculture. There will be differences, too, in the types of agriculture at which research will be aimed. Some countries will be primarily concerned with small farms and rural employment. Others will be concentrating on the commercial sector for both domestic consumption and export. Still others will be fostering a dualistic form of agriculture.

The strengthening of national research systems has generally proceeded incrementally. The accelerating rate at which new technologies are developed, combined with the speed of information flows and rapidly falling costs (at least in electronics), may offer opportunities for national systems to "leapfrog" over a whole phase (a generation) of technology. Already possible in communications and such areas as management information systems, leapfrogging may become an option in other technical fields as the years go by. National systems will need to keep their eyes open, both for the possibilities and for reliable sources of advice.

The accelerating pace of technology generation has another effect. The gap between know-how (the scientist) and do-how (the farmer) may well be widening in some subject areas. The concept of packaging (as employed in the private sector) may need to be invoked. New options should be presented attractively to the cultivator, who should be sufficiently educated to understand and decide among the available alternatives. ***Investment in the human capital of agriculture from basic education to advanced farmer training was constantly stressed in our consultation as an essential action if the opportunities of the future are to be grasped.*** The provision of on-line advice to computer-literate small farmers could become a reality in medium- and lower-income countries within the time-span of our forward look.

A subject which has not yet been sufficiently studied is the technology of institution building. This is a matter of great potential interest to national systems grappling with new modes of research and management and new ways of absorbing, generating, and diffusing information. This is also, of course, a subject at the heart of ISNAR's mandate.

At the Regional Level

For decades, the ideal of regional integration has been subject to opposing forces: economics favoring it where complementarities could be exploited or economies of scale achieved; politics alternately driving countries together and blowing them apart. Overall, the achievements of regional institutions in developing areas have so far been modest.

In agricultural research, the next two decades may well see a variety of different patterns emerging at regional and subregional levels. In Asia and Latin America, groups of well-endowed, largely self-sufficient national systems will want

to cooperate mainly for the exchange of information. Their needs for regional research facilities may be limited. Examples are permanent gene banks maintained in permafrost in the Andes and the Himalayas, or regional hot spots for disease screening. There are as yet no signs of a desire to establish a regional or interregional institution to conduct any very advanced or expensive research on behalf of all supporting countries. Nor is there yet any manifest ambition for important regional training facilities.

However, with rising self-confidence among a great many national systems, it would not be surprising to see a flowering of regional or (more likely) subregional arrangements, organized by the countries themselves in answer to a felt need and not donor-driven as has often been the case in the past. The role of the donor should generally be supportive and catalytic, rather than promotional. Subregional arrangements might be especially promising for joint research on crops that are not the subject of export competition, or for joint contracts for very advanced and costly projects.

The picture is different in Africa, because of the smallness of the average national system, the severe economic difficulties of most countries, and the failure of technology to develop satisfactory alternatives to traditional methods of cultivation in some of the most difficult ecosystems. As one participant in the consultation observed, what is needed is not technology for Africa but science for Africa.

There is a great deal of current discussion about modes of regional cooperation in Africa. The Southern African Centre for Cooperation in Agricultural Research (SACCAR) and the Institut du Sahel have been working together with the donor-created Special Program for African Agricultural Research (SPAAR) in the formulation of new ideas. One approach now being considered is the establishment of regional research poles for particular programs, to be located in national systems; activities for the region would be funded by a special slot within the national research master plan of the country concerned. Another set of ideas includes the creation of a research fund for each NARS, combined with the development of a pluralistic approach to national and regional research, within which the involvement of the private sector would be sought.

It would not seem appropriate for us to comment on proposals that are under current consideration. In our twenty-year framework, ***it seems necessary only to reiterate the importance of the national system as the basic building block, which should be supported but not substituted at the regional level.*** This philosophy will be indispensable for as long as the individual country is the unit for the exercise of sovereignty, the determination of self-interest, and ultimately the selection of priorities and allocation of funds. Regional institutions — short of full integration — must be based on alliances, and the history of every part of the world shows how quickly loyalties can change. Agricultural research is long, but alliances may be short.

The development of modes of regional cooperation in Africa, and to some extent in other regions, is a subject that will need lots of creative thinking and active doing over the next decade. Above all, the thinking and the doing must be directed at real problems, at the needs felt by the researchers of the region.

Well-intentioned outsiders may believe they know what the problems are and what the solutions should be, but to mount a program on such impressions is to build on sand. ***The most creative role for international organizations (including ISNAR) is to work with the people directly concerned in the construction of alternative models and approaches in research cooperation.***

At the Global Level

In our discussions, we did not look at the future role of the international agricultural research centers, nor of the CGIAR. Rather, we took a very general view of how the needs of national systems for international support may evolve in coming years.

Our findings, as reported above, have tended to emphasize the widening disparities between national research systems at different levels of development, facing different research problems and objectives, and confronted by different types of pressure. There will also be large variations in the roles played by the public and private sectors. We would expect to see considerable disparities not just between regions but also within regions.

International support to national systems will thus need to be flexible and able to cope with a wide range of needs. At the simplest level, it should provide a safety net under small and fragile national systems that could run into serious problems, through the departure of key staff, for instance. In a similar way, it should back up efforts to develop regional approaches along the lines discussed above.

New methodologies for the management of research and new methods of diffusing research results are bound to emerge. The international system can play an evolving role in helping national systems absorb this type of innovation.

Some NARS may need to be helped with issues relating to the private sector, with advice on the establishment of joint ventures, for instance, or on negotiations over patent rights.

An international, or interregional, approach may be useful for certain types of problems, notably those relating to environmental stresses.

Aid for agricultural research, and indeed for agriculture as a whole, has been on a plateau or showing symptoms of decline. This reflects in part the current complacency over world food problems and in part the arrival of issues with new and popular claims on aid funds. ***We believe that complacency over the outlook for food supplies is dangerous and that any weakening of the research effort could sow the seeds for disaster at some unidentifiable point in the future.*** National production systems in the world's most populous areas are more robust than they were a generation ago, but they are not invulnerable to repeated drought or disease. Surpluses on world markets can disappear even more quickly than they arise. And trade lifelines are still subject to political disruption. We are not saying that another world food crisis is inevitable, but the danger persists, and aid to both agriculture and agricultural research should

be kept up. Over the long haul, this will lessen the danger, and it will reduce the impact if a crisis comes.

The developing countries, especially the weakest among them, must be able to earn their way in the modern world. Countries without an alternative to agricultural exports will need to maintain their competitive position or develop new types of export through research. And for the poorest nations, research will require continued and generous international support for many years, and possibly decades, to come. But for every exporter, there must be an importer. Caution will have to be exercised by national and international policymakers before launching a long-term attack on markets where merciless competition may prove to be the undoing of many a hope.

Developing nations, industrial donors, and international organizations will all face new challenges in the world of the late twentieth century and the first decade of the twenty-first. But novelty must not be allowed to obscure the need for continuity. Agricultural research is being speeded up by new methods, but it is still slow. Twenty years is not an especially long time for bringing new technology from initial conception to universal diffusion. Strategy — whether it be for ISNAR, for a national system, or for an aid program — must blend continuity and innovation in the right proportions. To achieve the correct balance is not yet a science, it is still an art. We believe that our consultation, and the conclusions drawn from it, will help ISNAR in its task.

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