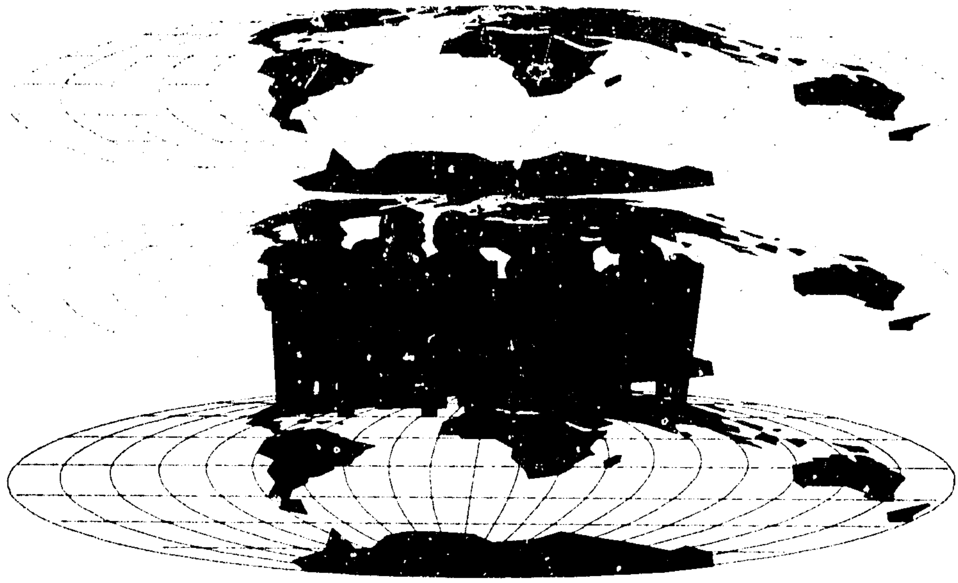
# Future Challenges for National Agricultural Research: A Policy Dialogue

**Proceedings of the international conference**
***Challenges and Opportunities for the NARS in the Year 2000: A Policy Dialogue***

Berlin, 12-18 January 1992



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The mandate of the International Service for National Agricultural Research (ISNAR) is to assist developing countries in bringing about lasting improvements in the performance of their national agricultural research systems and organizations. It does this by promoting appropriate agricultural research policies, sustainable research institutions, and improved research management. ISNAR's services to national research are ultimately intended to benefit producers and consumers in developing countries and to safeguard the natural environment for future generations.

ISNAR offers developing countries three types of service, supported by research and training:

- For a limited number of countries, ISNAR establishes long-term, comprehensive partnerships to support the development of sustainable national agricultural research systems and institutions.

- For a wider range of countries, ISNAR gives support for strengthening specific policy and management components within the research system or constituent entities.

- For all developing countries, as well as the international development community and other interested parties, ISNAR disseminates knowledge and information about national agricultural research.

ISNAR was established in 1979 by the Consultative Group on International Agricultural Research (CGIAR), on the basis of recommendations from an international task force. It began operating at its headquarters in The Hague, the Netherlands, on September 1, 1980.

ISNAR is a nonprofit autonomous institute, international in character, and apolitical in its management, staffing, and operations. It is financially supported by a number of the members of the CGIAR, an informal group of donors that includes countries, development banks, international organizations, and foundations. Of the 16 centers in the CGIAR system of inter

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**Sponsors:**

International Service for National Agricultural Research (ISNAR)
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# Preface

The seeds for the Berlin conference on Future Challenges for National Agricultural Research were sown in 1988, when the International Service for National Agricultural Research (ISNAR), the German Foundation for International Development (DSE), and the Technical Centre for Agricultural and Rural Cooperation (CTA) jointly sponsored a seminar in Feldafing, Germany, to examine the future evolution of national agricultural research systems (NARS) resulting from the changing dynamics of global agriculture. That seminar gave considerable emphasis to the challenges developing-country NARS will face as they

1. adjust to the consequences of policies pursued by developed nations;

2. become more conscious of the sustainability of the resource base for further agricultural growth;

3. take into consideration the changing role of agriculture in growing economies;

4. face declining support to agricultural research.

The policy environment of agricultural research emerged as a key actor in shaping the future of NARS.

Th Berlin conference was a logical continuation of the process initiated in Feldafing in two ways. First, it moved beyond the challenges facing NARS as they peer into the future, and it concentrated on the opportunities that are emerging. The challenges are no less than they were four years ago; in fact, they have grown in severity and in urgency. There has also been some change in emphasis — people are less concerned with global surpluses and more concerned with environment, especially as we come up to the Earth Summit. However, recent changes on the scientific and technological fronts have been dramatic and promise to be even more so in the near future. Such breakthroughs increase the effectiveness of research itself, as well as agricultural productivity. Similarly, we are witnessing significant changes in the institutional landscape that could have a profound effect on where research will be performed and by whom.

Second, this conference reinforced the overall importance of the policy framework as a determinant of the performance of national agricultural research systems, and it attempted to bring about a dialogue between NARS leaders and policymakers. The objective of the conference was to initiate a policy dialogue in an unconstrained forum where policymakers could discuss the issues with their research counterparts, free of internal or external political agendas. It was also an opportunity to inform one another of new directions being taken by institutions operating at the international and regional levels. This was a tall order for a single conference, and as ISNAR's director general stated in his opening address, one can only hope that this conference will be the beginning of a series of exercises in necessary policy dialogue. Over time this should set the stage for change from within as a response to the issues as they are objectively perceived by policymakers and NARS leaders, rather than as a reaction to outside pressures resulting from alien perceptions.

The conference was organized accordingly. The long-term world vision and its implications for agricultural research were discussed in the opening session. This was followed by an analysis of the policy environment seen from the perspective of donors, development agencies, and national leaders. More than half of the conference was devoted to the opportunities provided by the scientific, technological and institutional developments that are emerging and that will shape the future of agricultural research.

Fourteen papers were presented, following terms of reference tailored to the purpose of the conference. Authors prepared short, focused papers that presented the issues and stimulated discussions. Each set of presentations was followed by working groups that advanced the dialogue we were seeking, and then each set was completed by a plenary discussion. The discussions benefitted immensely from the diversity of participants and their expertise in the area. Developing-country participants came from all major regions and represented the range of levels in the policy-making process, from NARS directors and university vice-chancellors to permanent secretaries and ministers.

The organizers of the conference wish to thank the participants and all the authors who presented papers for their contribution to what we hope will be the beginning of an on-going process of policy dialogues.

*Paul T. Perrault*
ISNAR

*Engelbert Veelbehr*
DSE

# A Word from the Editor

This work comprises the proceedings of a conference, "Challenges and Opportunities for the NARS in the Year 2000: A Policy Dialogue," jointly sponsored by the German Foundation for International Development (DSE) and the International Service for National Agricultural Research (ISNAR). The conference was held at the DSE Conference Center in Berlin, from Sunday, January 12, 1992 to Saturday, January 18. The actual program and the list of participants are included as appendices at the end of this work.

All of the papers delivered are included in the order in which they were presented to the conference. A 44-page narrative summary of the entire conference, including discussions, was prepared by Dr. Howard Elliott, Deputy Director General of ISNAR, and is available as a separate publication ("Highlights of a Policy Dialogue: Future Challenges for National Agricultural Research," ISBN 92-9118-001-7, published by ISNAR in March of 1992).

A word about the acronym *NARS* is in order. *NARS* is a convenient abbreviation used in scientific agriculture circles for "national agricultural research system." Many words in English can be either singular or plural, so we have allowed *NARS* to function in this way also. Whether *NARS* means one or more than one research system is almost always clear from the context.

The editor says "thanks" to all of the authors who, without exception, in good humor tolerated the editor's tinkering with their words.

*Alan Mark Fletcher*
Ithaca, New York, USA
April 1992

# Challenges and Opportunities for the NARS in the Year 2000 and Beyond: A Policy Dialogue

Opening Address by
*The Honorable Mr. H. P. Repnik*
Deputy Minister of Development Cooperation
and Secretary of State
Federal Republic of Germany

With great pleasure I accepted the invitation to officially open this important international workshop, which has been organized jointly by the German Foundation for International Development (DSE) and the International Service for National Agricultural Research (ISNAR), and with support from our agricultural section and from GTZ.

I take this early opportunity to convey my sincere thanks to all those involved in the preparation of this workshop. I am especially enthusiastic about the wide range of experiences coming together on this occasion. Communication across the usual professional borders is all too often not happening — and this then leads to unwanted results; it even hampers progress now and then.

Studying the list of participants, one can only come to the conclusion that this must be a timely and highly necessary subject for an international workshop on development issues. Otherwise it would not have attracted such an esteemed group of participants and such outstanding speakers. Let me convey our thanks to all of you, who came from long distances in order to stimulate and promote the essential strengthening and improvements in such an important field of North-South cooperation, which does not always attract the responsible personalities. This time we have succeeded, and I take this as the best possible indication for a successful workshop.

Before elaborating on the subject matter, let me briefly voice a few remarks about the place of venue and the timing of this international workshop.

Berlin, our capital, is again a place of central importance with regard to commerce and trade, to industry and administration, to arts and culture.

Berlin these days demonstrates what politics can achieve — it recombines and integrates what had been separated for more than forty years. So Berlin in itself is an excellent selection, a splendid place for such an important international workshop, a place where one expects the unexpected to happen.

With regard to the timing, it is no secret that the meeting in its last phase coincides with Berlin's International Green Week — an agricultural exhibition for more than 60 years. This fair always opens its gates early in the year, right in the middle of wintertime in Europe. (I apologize that there is no snow right now, and the temperatures are rather moderate, but occasionally there are some organizational shortcomings — unexpected ones, of course.) And there is a quite simple reasoning behind this time schedule: it is much easier for farmers to leave their fields in winter, when there is no outdoor work to be done. So the International Green Week has always attracted many, many farmers, who take advantage of collecting as much information about the latest technology developments as possible.

Nowadays International Green Week is no longer a purely agricultural exhibition, however. It has turned into a food fair of international reputation, attracting many exhibitors from all over the world, and not only for primary products.

International Green Week over the years, and because of its attractiveness, has also experienced increasing importance with regard to workshops and seminars — both on a national and on an international level — dealing with new technologies as much as with the latest challenges from agricultural policies and politics and from technology developments.

It is by no means accidental that I have taken the liberty of talking about Berlin and its International Green Week to such an extent. Berlin and its International Green Week are a fascinating environment for an international conference aiming at nothing less than promoting national agricultural research for an improved standard of living for millions of people.

With these introductory remarks I want to emphasize that this workshop's topic is of central importance to agriculture and rural development, even with regard to economic development in general. At the same time, it becomes rather obvious that such a policy dialogue requires an atmosphere geared towards open and frank discussion if promising recommendations are to be achieved.

Now let us turn to the core of our program, to the challenges and opportunities for the national agricultural research systems in the year 2000 and beyond.

But let us first of all discuss some issues of the development policy of the German Federal Government, in general, and with regard to agricultural research, in particular.

The Federal Government emphasizes three areas as major challenges for its development cooperation:

1. poverty alleviation;

2. environmental issues;

3. education and training.

It is a well-established fact that development requires predictable and stable conditions that give people the opportunity to freely develop their skills and abilities. Sustained economic growth and scope for individual initiatives, active participation in political decision making, and last but not least, respect for human rights, are factors which affect and influence each other very strongly. One might even say that one is the precondition for the other.

Recently, fears have been expressed in Asia, Africa, and Latin America that the latest developments in Europe and in Germany could lead to a reduction in political interest and to a weakening of cooperation with the countries of the Third World. This is by no means the intention of the Federal Government. The Government emphasizes that cooperation between East and West and between North and South are *not* mutually exclusive, but mutually compatible. A unified Germany will, from its very beginning on, fulfil its responsibilities towards developing countries, as it has in the past.

A reliable, self-sufficient food supply continues to be one of the primary aims of the development cooperation of the German Federal Government. Lasting effects in this field will only be achieved where site-specific production methods designed to preserve natural resources are being promulgated.

Traditional food crops that are preferred by broad sectors of the population have a noticeable influence on the rotation of crops. Similarly, the integration of crops, trees, and shrubs is essential. Guaranteed yields at a relatively high level — even in the face of negative impact from weather — are the goal being sought with the development of new and improved farming methods.

An elementary prerequisite for successful agriculture promotion is a producer-friendly marketing and price policy that will stimulate production.

Cooperation in the field of agriculture also covers, among other things, the establishment and running of extension services, an efficient seed supply system, agricultural credit organizations, the cultivation and processing of agricultural products, and the all-embracing area of marketing, which also includes timely and sufficient supplies of commercial production inputs.

If the world's population continues to grow at predicted rates, then reliable food supplies will only be achieved if applied agricultural research is supported to an even greater extent than before. In this context, the foremost aim must be, in particular, reliability of yields under conditions of temporary drought and in the face of severe pressure from diseases and pests. Increased attention will likewise need to be paid to research into achieving optimal site-specific systems of production. With regard to this aim, the German Federal Government has supported the international agricultural research system of the World Bank Consultative Group since its early stages. I visited one of its outstanding research institutes recently, and I do not hesitate to admit that I am very impressed by the work done there.

But, nevertheless, since the implementation of new knowledge and research results are our aim, the strengthening of national research institutes is of utmost importance.

Small-scale farmers are less able to take risks. For this reason extension services need to be assured that their recommendations are well tested and thus safe for the farmer. For this purpose well-targeted investigations into site-specific cultivation methods need to be promoted still further.

As indicated before, it is a generally accepted fact that well-functioning national agricultural research systems are of crucial importance. May I just remind us that surpluses in the agricultural markets in the northern hemisphere are directly linked to progress and achievements from applied research.

It is also well understood that a straightforward technology transfer from North to South, even from one region to another, even on the same continent, seldom yields the expected results.

Agriculture under tropical and subtropical conditions is a rather complex activity that can only be improved by site-specific recommendations and solutions. This, on the other hand, does not imply that every country and even every region within a country needs its own full-fledged agricultural research system, dealing with every crop, with livestock and fisheries at the same time.

Since we are all aware of the severe budget constraints for national agricultural research systems, we shall support initiatives to coordinate and cooperate at a regional or interregional level. Burden sharing in this case can only be to the advantage of the ultimate target group. Burden sharing means splitting responsibilities for specific tasks between individual partners with comparable environmental conditions.

Agriculture will only be able to fulfil its potential role as the backbone of an economy if the decision makers allocate the necessary resources for the support structure; i.e., to the national research system, including agricultural faculties and colleges at the same time. Sustainable progress is only to be achieved if the exchange of information and experiences between the different institutions involved are strengthened. External support to NARS will be granted only where national planning authorities have this item high on their priorities list.

Priorities for research programs and investigations need to be based on national demands. Therefore, a thorough planning process is the starting point for improvements. Today it goes without question that not simply yield increases are aimed at, but that sustainable production systems need to be studied, comprising agroforestry activities as well as the integration of livestock into a crop production system.

Finally, let me just mention the time factor. Agricultural research and strengthening national agricultural research systems, in particular, are by no means fashionable. They are essential, though, and they require substantial and lasting support — from government, from donors, and from the commercial sector, too. Fashionable activities and the latest technologies might be useful tools, but they should never be regarded as a potential source of miracles.

With these remarks I have intended to stimulate your discussions, and I am confident that during the forthcoming week you will find some very important recommendations in order to turn the challenges into real opportunities.

I wish you a very successful meeting.

# Welcoming Address

*Peter Sötje*
Deputy Director General
German Foundation for International Development (DSE)

On behalf of the President of the Board of Trustees of the German Foundation for International Development (DSE), and on my own behalf, I have the pleasure to welcome you to this high-level meeting on "Challenges and Opportunities for the National Agricultural Research Systems in the Year 2000: A Policy Dialogue."

Looking around in this audience, I can see many outstanding personalities attending the conference. It greatly honors the German Foundation for International Development that all of you have considered it worthwhile to spend a few days of your precious time on our premises here to reflect on the vital issue of national agricultural research.

I am particularly pleased by the fact that the conference is taking place in Berlin. I should like to describe Berlin as the symbolic center for a unique process which poses tremendous challenges to policy-making. The German nation has to find policy solutions for a large number of serious problems, such as, for example:

- combining a market economy with a previously centrally planned economy;
- finding solutions for the unimaginable strain on the government budget;
- coping with a threatening and still-increasing rate of unemployment, particularly in the eastern part of Germany;
- eliminating the serious infrastructural deficit, not only in transport and communication, but also in many other sectors;
- finding solutions to the many environmental problems, both those created in the past and those newly arising;
- and, finally, solving the urban development problems of their city.

These are only some of the problems worth mentioning. Common to all these problems is that they pose a huge challenge, not only to policy-making, but also to research and research policy.

An interesting side aspect of the unification of the two former German states is the fact that the existing two research systems and research philosophies must also be unified, accompanied by a large number of difficult adaptation processes for all concerned.

A similar problem exists in many developing countries — similar in dimension — albeit entirely different in the details, though.

Even if not complete and certainly not fully applicable to all, many developing countries may be characterized by some of the following facts:

- Industry is frequently insufficiently developed, with the consequence that the national economy is mainly supported by the agricultural sector.

- Financing government expenditure from tax revenue is only possible to a limited extent, since monetary income generation frequently is not sufficiently high. As a result, governments in many countries suffer from an oppressing international debt burden.

- Many sectors suffer from a bad infrastructure.

- The rates of unemployment and underemployment are high, accompanied by still-high rates of population growth. In many cases, agricultural growth cannot cope with population growth, resulting in decreasing food security and increasing poverty.

- Partly as a result of unemployment and population growth, environmental problems increase. This is not only so in the fast-growing urban areas, but even more so in rural areas, where farmers are increasingly forced to expand agricultural production onto marginal lands, resulting in resource degradation and desertification.

All in all, the situation poses a serious challenge to agricultural research and policy-making. Too many priorities have to be satisfied with too-scarce financial, material, and qualified human resources.

The choking workload allows politicians and agricultural research directors little time to reflect on the actual or expected impact of their effected or planned decisions and activities, or to reflect on the reciprocal impact of policy decisions in different sectors. The impact of many a decision in one particular sector of the economy is or will be affected by the impact of decisions taken in other sectors.

The German Foundation for International Development is a private organization with a staff of about 550 people. Financed by the federal and state governments of Germany, its task is to contribute to the international exchange of experience on development problems and their solutions. Although the emphasis of DSE activities is on training (in the past 30 years we have trained more than 90,000 professionals from developing countries), DSE is also responsible for preparing and organizing international and national conferences, seminars, and expert meetings for the exchange of knowledge and experience. The aim of this instrument of dialogue is to elaborate strategies and concepts for different kinds of development problems or to disseminate existing concepts to specific target groups; for example, policymakers.

Within the frame of policy dialogue, DSE has been concerned with agricultural research for many years. A most recent example was an international conference jointly organized by the International Food Policy Research Institute and DSE in September 1991, at which senior agricultural research staff and policymakers from countries all over the world discussed the complex interrelationships between the need for increased agricultural production, agricultural sustainability, and poverty alleviation.

With the present conference, just opened by the Secretary of State, Mr. Repnik, DSE and ISNAR would like to provide the opportunity for high-ranking policymakers and agricultural research directors to reflect on the challenges and opportunities for national agricultural research systems in the year 2000 and beyond.

Society's demand for technological change has induced research in the natural sciences. As far as this research is concerned, and this, of course, also applies to agricultural research, it has mainly concentrated on conventional technologies in order to increase and intensify production. By the application of research results, agricultural production certainly has increased substantially, even if population growth frequently exceeds agricultural growth. However, the higher the level of production, the lower the incremental response to inputs of various types will be.

Certainly, in many less-developed countries there still is a large potential for agricultural growth by intensification of production. This also implies a substantial demand for basic agricultural research, particularly in the tropics. However, though the causes may be manifold, the increasing expansion of agricultural production onto marginal lands also indicates that advances in conventional technology may be inadequate in the future.

Society's demand for institutional change and more effective institutional performance prompts social science research. Here again a vast area of research lies ahead of us, and not only in the tropics.

All over the world there is growing concern over effective institutional performance and the returns of research, including agricultural research. Possible declining incremental returns to agricultural research will require a higher efficiency in the organization of research and will force policymakers to take uncomfortable decisions on the allocation of resources to agricultural research in times of growing resource scarcity and growing competition between institutions in various sectors for these scarce resources. It may be a matter of course to all of us assembled here to request an expansion of research capacity. This need, however, may not be as obvious to others.

It is this difference of opinion that forces us to think about the efficiency of the present organization of our agricultural research, both national and international. We must ask ourselves whether the division of labor between existing agricultural research institutions is really optimal before we can start thinking about the creation of new institutions. We must reflect on the adequacy of present resource allocation to institutions, and not only to institutions, but also to sectors and technologies to which these funds are devoted.

And, last but not least, we should consider the adequacy of incentives offered to the qualified scientists working in our institutions and their so-much-needed support staff.

Our planet is growing smaller in a double sense: first, a still-exploding world population rapidly decreases the available arable land per capita and puts tremendous challenges to the world's scientific community, including educational institutions and extension services. During the several decades of development cooperation, the problems certainly have not decreased but have rather only become more obvious.

In a second sense, our planet has become smaller due to much more efficient communication facilities and international air travel. The two factors have made it possible for all of us to assemble here in Berlin and discuss the challenges we are facing and the numerous opportunities out of which we must make our choices.

Excellencies, honorable guests, ladies and gentlemen, may your deliberations on our premises here in Berlin take place in a friendly atmosphere and lead to future-oriented results that may serve the present and coming generations of all our peoples.

# Opening Address

*Christian Bonte-Friedheim*
Director General
International Service for National Agricultural Research (ISNAR)

May I welcome you and thank you all for having accepted the joint DSE/ISNAR invitation for this policy dialogue.

Minister Repnik, may I address you directly and thank you! Only the financial support from your government allowed ISNAR and DSE to plan and implement this dialogue. Also, I believe that all of us very much appreciate the fact that you have come here specifically for this occasion, to open our dialogue and to be with us during this ceremony. We thank you for your stimulating address, on which we will certainly reflect during the coming days.

Minister Repnik, besides the thanks for this opening address there are some other thanks I would like to pass on. First, to you and through you to your Ministry, and to the German Government, may I express the appreciation for long-term continued substantial financial support to our international system, known as the Consultative Group on International Agricultural Research and to its now 16 international institutes, and to international agricultural research in general. Furthermore, and very specifically, Mr. Minister, I want to thank you personally for the special and considerable financial support to one of our sister institutes, the International Rice Research Institute (IRRI) in the Philippines. There is little doubt that the timely German support to IRRI was possible only because of your personal intervention.

My special thanks also go to DSE, and above all, to Feldafing. We have enjoyed working together in the preparation, we have become partners, and I am certain we will enjoy the dialogue, convinced that it will make a contribution, hopefully a very major contribution, to the effectiveness and efficiency of future national agricultural research in many countries.

The dialogue during the next few days reflects the need for interaction between policymakers and research leaders and between people with similar problems and similar concerns. All of us are, or should be, concerned about three possible issues which we might face at any one time within the coming two decades. These concerns will be reflected in much of what will be discussed during the next few days and can be identified as follows:

1. possibly a national, regional, or global food crisis;
2. possibly a regional or global rural-poverty crisis;
3. possibly a national, regional, or global environmental crisis.

If we are convinced, or if we can be convinced, that such crises will not take place, then and only then do we not need to be concerned with agricultural research and agricultural research policies.

Honorable ministers, vice-chancellors, permanent secretaries, and other guests, I promise that this Berlin policy dialogue will turn out to be one of the best meetings you have ever attended. This will not be a North-South dialogue, but a South-South dialogue. (In this context Australia and New Zealand belong to the North and not to the South.)

In agricultural development and agricultural research, the countries of the South have a lot in common, in spite of all differences. Most of the differences stem from the size and historic, political, social, and cultural conditions and development. Bhutan, for example, has a population of about 600,000 and about 31 person-years of national researchers, but also has six agroecological zones, based on rainfall and altitude. Its neighbor India has a population of about 800 million and more than 8,000 person-years of researchers. And China has more agricultural researchers than all other countries represented here have together.

In the North, agricultural research started centuries ago, with private farmers breeding new plants and animals. Research related to agriculture has taken place in universities and similar institutions, however, for scarcely more than 150 years. Around the middle of the last century small village artisans were developing equipment and machines. Then small industries undertook research work in agricultural engineering, developed chemicals for plant nutrition and protection and for animal health. Only towards the end of the last century did governments create public-funded agricultural research institutes. In a general context, NARS have existed for only about 100 years. For many reasons, there has been an easy transfer of technologies between countries of the North.

Many countries of the South started their agricultural research with public-funded national agricultural research with NARS, copied this mandate, structure, organization, and other relevant aspects from the North, with researchers trained in the North, who often knew very little of farming in their own country. Research priorities were not set by farmers, but by others.

In the North, the agricultural research agenda is influenced by surpluses and pollution. Marginal natural resources will not be needed for production and will be set aside. Not production increases, but cost decreases, will dominate the future research agendas. In the South, agricultural production must move into marginal areas, and production increases are necessary, permanent features of agricultural policies. Public-funded and private research in the North attempts to find substitutes for imported agricultural products from the South. Research in the South also aims at finding new markets in the industrialized countries. In future there may be less spillover from agricultural research results and technologies developed in the North that could be of benefit to the South. Furthermore, many new technologies have the potential for patents and other appropriations and will no longer be free. In future, charges and levies must be expected for the transfer and application of some technologies from the North.

The South, while reviewing and evaluating different experiences from other regions, must find or develop its own solutions to the many technical and institutional problems of agricultural research. Regional research is being promoted and advocated as a solution, but regional research can easily drain human and financial resources from NARS and can lead to research programs that do not necessarily reflect national priorities. Regional research also needs strong NARS; it can easily supplement, but it can seldom substitute for, national research.

In most countries of the North, the public views its own agriculture, unfortunately, in very specific and not always very complimentary ways. Typical characteristics of agriculture in the public opinion are conservative, protective, uncooperative, selfish, over-exploiting resources, resisting change, and insensitive to other developments, just to name a few. Policymakers from the South, educated in the North and besieged with information from the North, often adopt these views under quite different circumstances in their own countries.

We in the South — and having lived in or worked exclusively for the South for nearly 30 years, I dare to say "we" — should not copy or accept this picture for our agriculture, which is the backbone of most economies. We need partners, supporters, and friends; we need to be forward-looking. But the importance of our agriculture must also be recognized. Where does the minister for agriculture rank in the cabinet? Where does he or she sit around the table of ministers?

The worldwide discussions about natural resources, about agriculture and agricultural research, are dominated by arguments of justice and fairness. The North is pleading for fairness between generations, fairness for future generations, or *inter*generational fairness. The South is pleading for fairness within generations, or *intra*generation fairness. When the Berlin wall was built, in Africa south of the Sahara the gross national product (GNP) per capita was about 4% of the GNP of the industrialized countries of the North. About 30 years later, in 1991, the comparative figure is less than 2%. The difference between rich and poor has grown — the rich have become richer, and the poor have become poorer.

There is little doubt that agricultural research has made considerable progress and supported the necessary production increases in many countries, especially in the larger Asian countries and also in Latin America. But will it continue?

My promise for the best dialogue that you ever have attended is based on you, the participants, your experience, your willingness to share with each other, to learn from each other, to improve, to change, and to overcome. While in Berlin you will also have an opportunity to visit the world's largest food fair, Green Week. There you will be able to see for yourselves the competition you will face in export markets and the many choices that consumers in industrialized countries have.

How can we measure any impact of this dialogue? You will return home, hopefully with new knowledge, new experience, new friends. If in the future you make use of this widened horizon and your new friends, then the dialogue will have had tremendous impact. ISNAR and DSE will prepare a proceedings for you to use as reference material, should this become necessary, and as advice for others who have not attended.

All of us are aware that this dialogue cannot cover all of the agricultural research policy issues. Unfortunately, the agenda cannot even include all of the most important issues. Many of the issues will be raised within the working groups; others must be discussed in different forums at other times. A major concern to many of us is linked to the institutional sustainability of agricultural research in many developing countries.

To my colleagues who present introductions to the various topics, I make a specific request. Let us make maximum room and give maximum time for dialogue. We will be flexible and will reflect the need to adjust and change the program as we go along. Let us not be teachers or professors, but animators. Let us only raise the issues for the dialogue. Let us not pretend that we know the answers, even if we believe that we know the problems and issues.

I have a dream. I can see that on Saturday we might have a number of recommendations resulting from our discussions. Included in the list there may be a request to the German Government to repeat these dialogues in connection with the International Green Week, to plan such an event every year or at least every two years. These dialogues will be improved each time.

Perhaps in future the last day of our meeting will be used for a dialogue with policymakers and research leaders of the North, who traditionally come to Berlin for Green Week. Should the German Government accept such a recommendation, then on behalf of ISNAR I offer our services to assist in the planning and implementation of these dialogues and their specific topics.

Let me close with a plea for more understanding, more solidarity, and more compassion for the underprivileged, a plea for recognition that, more than ever before, we live in one world, hopefully a more just world for the next generations. The great Indian, R. N. Tegore, who won a Nobel Prize in Literature, wrote in 1908:

> We have for over a century been dragged by the prosperous West behind its chariot, choked by the dust, deafened by the noise, humbled by our own helplessness, and overwhelmed by the speed. . . . If we ever ventured to ask — progress for what, and progress for whom — it was considered to be peculiarly and ridiculously oriental to entertain such doubts about the absoluteness of progress.

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# Challenges Facing Agriculture in the Next Century: Issues for National Agricultural Research Systems

Keynote address by
*Louis Emmerij*
President
OECD Development Centre
Paris, France

When we look at the world agricultural and food scene today, we see that we are faced with several challenges which, most probably, will still be with us into the next century. First, there is the elimination of hunger, which is not so much a production issue as a redistribution issue, because the food supply will be sufficient to meet world demand. Second, there is the elimination of agricultural protectionism in OECD countries, which continues to be a major issue with significant implications for developing countries. Third, there is the need to increase agricultural yields in the developing countries.

In this paper, however, I shall concentrate on a fourth challenge: technological change and innovation in agriculture.

## The Forces Influencing Technological Change and Innovation in Agriculture

To understand the forces influencing the pace and nature of technological change in agriculture, it is useful to view the agriculture sector — and agricultural technology — within the overall context of factors shaping technological change and innovation.

First, technological innovation is an essentially interactive process, involving linkages and networks ("network relationships") among different organizations and actors, particularly industrial enterprises. If they don't have these linkages, developing countries will be frozen out.

Second, innovation and diffusion are the result of a technological learning process (learning-by-doing, learning-by-using, and learning-by-interacting) which involves both users and producers. The combination of learning and experience is an essential element in the process, which is termed "technological accumulation." A base of technological change must therefore be established in developing countries.

Third, the transition to globalization of economic activities has been an important trend. An increasing proportion of worldwide production and distribution occurs within a system of interlinking private networks. The major participants in this new configuration are large multinational corporations (MNCs) which deploy their resources and activities worldwide. Within some industrial sectors, oligopolistic rivalry is giving rise to new types of long-term alliances and agreements with other firms (network corporations), including former rivals. Whereas, in the past, concentration was measured by domestic market shares, with globalization the only meaningful measure of concentration is the share in world markets, developed through international mergers and takeovers. This is giving rise to what can be described as "international oligopolies," and raises new questions of access to scientific and technological information, particularly for developing countries.

## *Technological change and growth*

If we agree that technological change is basic to long-term economic growth, continuing differences in output must be linked to variation in the ability of countries to acquire and diffuse new techniques. In the light of the recent widespread emergence of structural adjustment, not only in developing countries but also in the hitherto centrally planned economies, it is useful to consider how far spontaneity can be expected to stimulate technological change in agriculture and the ways in which — particularly in low-income countries — the increased emphasis on market incentives may or may not be conducive to technological change.

The "catching-up" hypothesis developed for industry suggests that the larger the initial technological gap in the use of "best-practice" techniques, the greater the potential for catching up. While in some situations the catching-up concept may be applicable (for example, wheat in the Punjab), in others catching up can be inhibited by a combination of technological backwardness and lack of what has been described as "social capability."

It can be argued that the success of late-industrializing countries is due to learning and imitation rather than to domestic innovation. Following this reasoning, technologically backward countries should devote more effort to "development" (rather than "research") and to adapting technologies designed elsewhere.

Explanations of technological accumulation, innovation, and diffusion in industry may not be directly applicable to agriculture, however. Natural resource endowments (climatic and soil conditions) are still important in the production of food crops. In addition, technology transfer and imitation may be inhibited by the location-specific character of agricultural technology.

No one denies that there is a very wide technological gap between many developing countries — particularly in sub-Saharan Africa — and the rest of the world. Can this be accounted for by technological backwardness and lack of a "critical mass" of scientists, technologists, and infrastructure? Might it be accounted for, at least in part, by social capability and, if so, is it possible to begin to define and measure this?

In agriculture, producers might be expected to respond to market and price incentives by introducing minor, incremental technological change (introducing better seeds, improved implements, and better storage facilities) which would have considerable impact on output. Public participation is essential to provide roads, credit, agricultural research, and extension services. Public provision of agricultural services can be expected to result in a higher rate of growth than would result from spontaneity or "laissez-faire." The development of research capacity requires education and infrastructure, suggesting that market incentives must be supplemented with public investments if the challenges of technological development are to be met.

## New Biotechnology and Agriculture

New biotechnology lies at the center of the debate over the influence of institutions on technological change and, conversely, the influence of technological change on institutions. It is also an important element within the debate concerning sustainability, in which expectations of environmentally friendly plant and animal nutrients and biological controls are seen as an appropriate response to growing concerns about fertilizers, pesticides, and other chemical compounds increasingly viewed as unsustainable pollutants. Can it be anticipated that environmental pressures are likely to stimulate the development and diffusion of biotechnologies for more sustainable agricultural production systems? Or will regulatory processes, problems related to the protection of intellectual property rights, and public fears over the new technologies in food and agriculture inhibit their development? And what are the implications for developing countries and their agricultural research systems?

It can be argued that the high prices and protected markets in OECD member countries stimulate biotechnology innovations which could further distort markets. However, it is at present unclear, particularly with respect to plant biotechnologies, which techniques will be profitable and how structural adjustment and liberalization might affect profitability. Environmental concerns are also expected to alter the criteria governing production, consumption, and trade, with non-tariff barriers associated with chemical residues and food regulations increasingly acting as a form of barrier to developing-country exports.

Except in the field of health care, few new products have yet reached the market. The first important wave of biotechnology products is expected from 1992 to the year 2000. In the longer term (50 years hence), biotechnology may be essential in helping to preserve the physical environment, coping with possible climatic change, and feeding growing populations.

In plant biotechnology, the major techniques currently being investigated involve genetic modification for various kinds of stress resistance, plant breeding, plant production, and enhancement of plant quality, in turn linked to food quality. Contrary to earlier expectations, developments have been more rapid in animals than plants: animal health (diagnostic tests and kits, vaccines, therapeutics), growth, and lactation; animal feeds; embryo multiplication; genetic engineering of animals.

In food processing, among the many new techniques being developed are monoclonal antibodies used to enhance food safety and prevent contamination, enzymes, bio-preservation, new foods, and new plant cell cultures for flavors, fragrances, etc. It is anticipated that consumer preferences, as well as food safety concerns and regulations, will be of overriding importance in the diffusion of new food-processing techniques.

For developing countries, biotechnology presents both opportunities and threats. The opportunities include prospects for raising production, enhancing nutritional properties and quality, lowering dependence on agrochemical inputs, and helping to conserve biodiversity. The threats stem from the possibility of a widening technological gap due, on the one hand, to an inability to develop or utilize the new technologies, and on the other hand, to the lack of an appropriate legal framework for protecting intellectual property rights.

It is interesting to compare some of the essential characteristics of the new biotechnologies and their potential impact with those of the more traditional technologies. It is also worth noting that earlier predictions that biotechnologies, particularly plant biotechnologies, would be commercialized by 1990, have not been realized.

Although the plant biotechnologies at present being developed will control some stress factors, they will not increase yields. This will require complex techniques of multiple gene transfers which have not yet been mastered.

The Green Revolution technological package was introduced at a time when there was considerable pent-up derived demand by farmers. At least with respect to crops, no such derived demand exists for the new biotechnologies, particularly because cheaper ways of coping with stress factors may be available. At present the early plant biotechnologies appear to offer little profit incentive for farmers. It can therefore be argued that incentives to the R & D and farm supplies industries may be required in order to diffuse the new technologies at the farm level.

As with earlier technologies, biopesticides, disease resistance, etc., will be mainly embodied in germplasm and will therefore pose no particular adoption problem by developing-country farmers. However, the situation is quite different with respect to animal biotechnologies. Apart from some of the animal vaccines and improved feedstuffs, the use of techniques such as bovine growth hormone and improved reproduction techniques for animals will require relatively sophisticated management capability on the part of farmers.

One positive aspect of the new biotechnologies for developing countries is that they would not have the same dramatic impact on labor utilization as the earlier mechanical technologies. The new biotechnologies are perceived as being less labor-saving and, if appropriately marketed, essentially size-neutral.

In contrast to the Green Revolution technologies, which were developed as a public good with the support of philanthropic foundations and the early international agricultural research centers (IARCs), a large proportion of research and development (R&D) on the new biotechnologies is being carried out within private-sector firms. Because the research effort will likely be highly capital-intensive, firms will make more effort to protect research results. This raises questions of the potential for monopolistic behavior by private firms and of access and control for farmers.

The combination of privatization of the new biotechnologies, and emphasis on market forces as an outcome of structural adjustment, implies that the prospects for biotechnology will be most favorable in developing countries whose private involvement in innovation is already developed and/or where the private sector has incentives.

## Biotechnology and Industry

Recent research for the OECD Development Centre focusing on the investment strategies of leading agro-food companies suggests that involvement in biotechnology is an essential aspect of competitive strategies. However, because of the high level of uncertainty among the major actors themselves, the uncontrollable nature of key scientific, economic, and other variables, and difficulties in establishing R&D priorities, network relationships have become a permanent feature of negotiations in assessing the costs of introducing and developing the new technologies. At the same time, there appears to be stronger emphasis on in-house competence. This is a result of a perceived need to control markets through intellectual property rights protection and, more specifically, through patenting.

Differences can be observed in the way biotechnology is perceived upstream and downstream. Upstream, biotechnology is an essential component of competitive restructuring in the seed and agrochemicals industries. Downstream, biotechnology is one of a series of options dominated by the need to establish competitive strength in global markets, which are increasingly segmented according to quality.

The interest of the major firms in developing countries is concentrated on those countries which already have a strong agro-industrial base. The impact of trade liberalization in the context of the GATT negotiations does not enter into their calculations. The major firms favor markets in which they are already present and operating, where currency is stable, inflation is controlled, and intellectual property rights are respected.

Breeding programs that incorporate research on modern biotechnology are increasingly concentrated in the industrialized countries. Nevertheless, many firms express interest in the direct transfer of research capacity to developing countries to conduct programs defined by governments or international bodies. This may open the way for new models of technology transfer, but may also imply privatization of important segments of biotechnology research in developing countries.

## Structural Adjustment and Technology

The possible negative effects of structural adjustment on poor farmers, particularly in African countries, is a source of great concern. In these countries the need to cushion small farmers — and consumers as well — from greater price variability during stabilization and adjustment is the most pressing, but in them the lack of cost-effective institutions to manage risks, particularly for small farmers, is most apparent.

In the past, risk management was inherent in different public-policy instruments. With adjustment, farmers are likely to be exposed to greater price variability, and it is therefore important to investigate ways and means of risk management. In practice, whereas the public sector may continue to have an important role, a role for the private sector may also be nurtured; for example, through drought and crop insurance.

In examining the impact of the structural adjustment and liberalization process, it is important to make a distinction between stabilization measures that are designed to address short-term imbalances in external trade and the internal budget account (which involve large-scale reductions in public expenditure, sharp increases in interest rates and devaluation), and structural adjustment proper, which is longer-term and would involve a shift in production to tradable sectors, divestment of state resources, measures to encourage private-sector involvement, liberalization of markets, deregulation of prices, and subsidy removal.

Whereas in the 1980s stabilization tended to dominate the policy arena, in the 1990s structural adjustment is expected to be manifest in a fundamental liberalization of markets and a shift in the public-private balance. Thus farmers in developing countries will increasingly be faced with deregulation of prices, subsidy removals, and the privatization of public enterprises. Public investment in infrastructure and research is also expected to be severely curtailed.

The findings of research on the impact of stabilization and structural adjustment concur in some respects but diverge in others. Structural adjustment can have major effects on the structure of agricultural incentives and on price relativities between internationally tradable and nontradable outputs. In general, the effects are pro-agriculture. In principle, the broad impact on the use of resources in the agriculture sector would be to encourage the use of nontraded resources such as labor and land rather than fertilizer, chemicals, energy, and machinery. In the aggregate, it might then be expected to be pro-poor.

Evidence also points to problems of transition, which can have quite dramatic implications for technology in Africa. Improved high-yield varieties that require storage and chemicals treatment may be abandoned. Mechanization and large-scale irrigation schemes may also be abandoned or reduced in intensity. Technological regression—such as the abandonment of hybrids for open-pollinated varieties—may then occur. On the other hand, changing input-output price relationships may serve to revive certain export crops; for example, cocoa.

Research examining the range of macroeconomic policies and institutional changes brought into play has tried to trace these through to the microeconomy and to smallholders. In some countries, and in some respects, the desired changes have taken place. From the evidence available, smallholders producing tradables have benefitted from adjustment. And, in contrast to the popularly held view, not only export-oriented farmers have gained; producers of food crops have benefitted from a reduction in the competitiveness of imports.

On the other hand, evidence suggests a sharp decline in the rural services that are very important to small farmers: equipment supply, hire, storage, transport, animal health services, plant-protection services. This raises questions about withdrawal of public funding for such services and the extent to which private-sector involvement can be expected.

Another important effect of stabilization and structural adjustment programs is their inevitable impact on public research. Public-sector agricultural research has been a sheltered area in adjustment because it has been argued, first, that this is a genuine area of market failure where private supply would be socially suboptimal and, second, that the inventory of "on-the-shelf" technology has been smaller than originally thought. In most countries, an inordinate proportion of funds is absorbed in salaries, and underfunding and management problems are endemic. In principle, institutions should be made more sensitive to cost recovery and more accountable to client demand. However, there may be limited scope for divestment of public research institutions, except in the seed industry.

In Africa, in particular, public-sector agricultural research is likely to suffer from problems of donor fatigue and coordination failures. These problems are compounded by the lack of domestic technical and managerial capacity to ensure implementation.

## Issues for National Agricultural Research Systems

Proponents of structural adjustment and liberalization argue that it will result in better price signals and in stimulating competition. This will be conducive to the development of agricultural systems that will have true comparative advantage in choice of crop, location, processed product, and technology. Proponents also stress the importance of links with international markets and of the role of foreign investment.

The hypothesis that widespread adoption by small farmers requires specific institutional interventions by the public sector, which should make major investments in extension, input supply, and credit, has also been challenged by the proponents of structural adjustment. Instead, they would advocate industry-based extension services and private suppliers of agrochemicals and seeds. Similarly, the proposition that price liberalization and the removal of subsidies would inhibit the adoption of new techniques by smaller farmers, who should therefore be provided with incentives to induce them to take the risk, has been questioned by advocates of structural adjustment. Ongoing work at the OECD Development Centre, and elsewhere, is assessing the impact of structural adjustment on agriculture and on agricultural technology and will throw light on the validity of these different hypotheses.

A central issue raised concerns the conditions necessary, for countries at different levels of development, for stimulating technological change and diffusion. One important aspect of this issue is risk, or at least to the perception of risk, by farmers, and the consequent need, first, to identify the groups most at risk and develop ways and means of managing the risk.

A second aspect is the availability of profitable technologies for small farmers. One view holds that there is a dearth of technologies that would be both appropriate and profitable for small farmers. The other view argues that technologies are, indeed, available but the sets of policies in place do not provide incentives conducive to risk-taking by farmers.

An additional aspect, which is linked to developer/user questions, is that of the transfer of technology versus local research. To what extent does location-specificity inhibit the importation of biological techniques, or at least necessitate a period of adaptation to local agro-climatic conditions? Clearly, the responses would differ for different techniques and for plant and animal technologies.

It can be argued that productivity gains in developing countries will, at least in the short term, continue from the diffusion of traditional techniques rather than from new biotechnologies. With respect to plant crops, the new techniques will complement but not supersede those of Mendelian plant breeding.

The agro-food system is one in which a number of participants (markets, firms, farmers, governments) are linked, through technology and information networks, at the farm, firm, national, and global level. The essential question for developing countries is, then, whether the system is open or closed, and where "windows of opportunity" are to be found.

## Conclusion

The structural reform process implies a larger role for the free market in the economy and diminished state intervention. Recent examination of investment trends in R&D in OECD member countries suggests that private firms are not prepared to assume the role, earlier considered to be the responsibility of the public sector, of investing in long-term basic research. A strong case has therefore been made for a continuing role of the public sector in the basic sciences underpinning the new technologies. It is also argued that government intervention is necessary to stimulate interactive networks at the national, regional, or local level to energize technological innovation and as a countervailing force against the globalization trends which to a large extent escape national control.

In some developing countries the problems of striking an appropriate public/private-sector balance are compounded by states that are weak and vulnerable, and do not have the administrative capacity to implement structural reforms. Also, sometimes — but not always — in these countries, markets are so weak that the role of the state cannot easily be terminated. The proper role of government in agriculture, agricultural research, technology development and dissemination, and institutional infrastructure will, of course, depend on individual countries, on the "social capability" existing in each country, and on market structures already in place.

The ways and means of inducing the private sector to play a more active role, both in agricultural research and in the provision of agricultural services to small farmers, is an important research issue. One of the problems lies in the fact that producer groups in developing countries are seldom organized as clients of research to the same extent that they are in industrialized countries. Clearly, it is important to examine the potential for collaboration and complementarities in research between the public and private sectors.

The challenge for NARS in the coming decades will be to define their contribution to sustainable rural development in the context of economic liberalization and adjustment. This places an increased emphasis on the private sector and market forces. But, the private sector may be as imperfect as the state may be incapable. The comparative advantages of the state and the private sector need, therefore, to be carefully analyzed and the role for NARS identified as providing a public good. In particular, the NARS need to ensure that research reaches small and poor farmers, and that developing countries have the "network relationships" and the "technological accumulation" to ensure that they are able to grow. This responsibility is absolutely central to any development strategy.

With these strategic objectives and the domestic division of labor between private and public in mind, the role of NARS in the international, regional, and national research effort should be wholeheartedly commended and strengthened.

# The Role of Research in the Global Agricultural Development Challenge: An International Perspective

Keynote Address by
*Michel Petit*
Director, Agriculture and Rural Development Department,
The World Bank, Washington, DC
and
*Suzanne Gnaegy*
Consultant

## Introduction

In this brief presentation we attempt to advance an interpretation of the role of research in global agricultural development from an international perspective. More particularly, we analyze the impact of international developments on the demand for the output of research and on the supply of the resources required in order to produce research. Thus, research is seen as an activity creating knowledge and technology, technology itself being a product of knowledge.

## The Demand for Agricultural Research

Several observations can be made concerning the demand for agricultural research. First, there is currently a stagnation in the level of funding, both by the international development community and through reduced domestic budgetary allocations to national agricultural research systems (NARS). These coincide with low world commodity prices, which may lead one to wonder whether there truly is a need for agricultural research to provide us with greater productivity. Yet the answer to this is that the need for agricultural research remains as great as ever. The conclusions of a report recently completed by the Agriculture and Rural Development Department (AGR) of the World Bank suggest that diminishing land and water resources, coupled with global demand for grains doubling over the next 38 years, mean

The interpretations and conclusions in this paper are the authors' own and should not be attributed to the World Bank, its Board of Directors, its management, or any of its member countries.

that in order for productivity to increase accordingly (2.3% per annum), more of that productivity will have to result from new knowledge and technology.

In the context of global agricultural development, this need is reinforced by the need to maintain each step along the food chain, while at the same time assuring the continuing productive capacity of the natural-resource base. We will discuss each of these factors which influence the perceived need, or demand, for research.

### *Productivity requirements*

The authors of the report referred to above project that by the year 2030, global consumption of all grains will total 3.3 billion metric tons — twice the amount actually consumed in 1988-89 (AGR 1991: 8). In that paper, productivity growth in agriculture is said to rely on two primary sources. The first source is current knowledge that is either underutilized or incorrectly applied, but would prove to be more productive than that in general use now. The second source is new technologies and practices that incorporate new knowledge — in particular as developed through agricultural research. This first source could very well increase both land and water productivity, but the second source offers more promise for productivity increases than any other direct assault on the constraints to that productivity.

Quoting from the paper, "... the only way higher costs can be avoided is to increase knowledge about agricultural production practices by investing in the people working in agriculture and in the technical and institutional innovations they will need to increase the productivity of their resources" (AGR 1991). In the context of increasing yields, this will mean the expansion of the uses of biotechnological solutions, further investigation into the environmental costs of fertilizers, the development of more efficient means of irrigation, through both technological and management improvements, and the continued search for better crop-management practices.

Research directed toward increasing productivity must be made at generally acceptable economic and environmental costs. Thus the management of natural resources will need to be an additional focus of agricultural research, helping to ensure the sustainability of productivity gains over the long run.

### *Management of natural resources*

Improvements in the management of natural resources such that sustainable agricultural development can take place over the long run will require special effort by the agricultural research establishment. As noted in the above-referenced paper, supplies of plant genetic resources are least likely to limit productivity increases, but since much of this genetic diversity is found in countries that are unlikely to be able to meet the cost of conservation of those resources, a sustained international commitment will be required to help in the task. As for climate as a resource, we know that there is likely to be global climatic change as a result of global warming. Although we cannot easily predict the magnitude of either the changes or the effects of those changes on production, we do know the likely direction of those changes. The research community will need to respond to these expected changes by at the very least exploring the possible options for continuing production, given a range of probable climatic conditions.

Agricultural research can address questions about both the quantity and quality of land resources. It can be done through the development of husbanding techniques that would allow previously nonproductive lands to be used in crop, livestock, or forest production. At the same time, while there is much concern about general land degradation, little research has been done on just how much is occurring and at what rate. The real constraints to land opening up to agriculture, however, will be the economic and environmental costs of land use. Both of these issues can be investigated by agricultural research.

The water resource, not unlike land, is the most complicated because of the difficulty in establishing clear, well-defined property rights to the resource. This problem manifests itself in poor or nonexistent markets for water, which in turn results in poor management and government control. Again, although the property rights question is only marginally within the purview of agricultural research, a multidisciplinary research effort can be directed at questions related to the use and pricing of water, gains in the efficiency of management, and the restoration of land and soil quality by addressing issues such as salinity and waterlogging.

Agricultural research has a very important role to play in this context. Put in economic terms, ". . . a dollar invested in increased knowledge about management of agricultural resources will return more in net social product from agriculture than a dollar invested in expanding the supply of natural resources within the existing knowledge regime" (AGR 1991).

### *The food chain*

Agricultural research will have to expand its mandate to include research on all steps of the food chain, from production through processing, marketing channels, storage, transportation, meeting nutritional requirements, and addressing changes in consumer preferences. These elements of agricultural development are essential to satisfying the demand for food at every level. The private sector is probably better suited to initiating research on most of these issues, but the international agricultural research network can be a part of the solution by helping to identify where needs are and what might be done to satisfy them.

An example of international efforts that contribute directly to this body of knowledge is the International Food Policy Research Institute (IFPRI), which has collected primary data concerning household incomes, expenditures and nutrition patterns, investigated how technological change in agriculture affects national economic growth and the welfare of the poor, and examined national and international policy issues that affect food availability and the structure of incentives in agricultural production.

## The Supply of Resources for Agricultural Research

What resources are likely to be available to agricultural research, to render it capable of satisfying the demand expressed above? The resources we already know are available to us through the international agricultural research organizations, the private for-profit research network, and the national agricultural research systems. But many factors influence the availability of these resources to provide the research when and where it is most needed.

Given the current state of the global economy, and the likelihood of budgetary cutbacks that will eventually affect the resources available to agricultural research, the question will inevitably be one of deciding where and how to spend limited resources. By clearly defining the roles of the various participants in agricultural research, we can work towards a more efficient expenditure of those declining resources.

### *The national agricultural research systems*

The continued debt problems of so many countries, macroeconomic imbalances resulting from exchange rate and industrial protection policies or producer support prices, the tendency to direct government spending towards crisis management rather than sensible long-range planning, the shortage of hard currencies these countries have at their disposal, and the continuing urban bias discriminating against agriculture do not bode well for the prospects of continued funding of national agricultural research activity. Certainly some of the pressures on public financing come from factors beyond the control of domestic policymakers, such as the decline in world commodity prices or the increase in oil prices. However, there are also factors over which countries can indeed exercise control, and which have recently caused the donors to reexamine the intentions and effectiveness of national policy initiatives.

Certain policy environment issues will determine, to varying degrees, the capacity of developing countries to meet the challenges outlined in the previous section. The debt issue is perhaps no longer perceived so much as a crisis as an endemic problem with which many countries will be continuously struggling. Some countries have attempted structural adjustment programs, but in many cases the policy reforms have been incomplete or have in turn resulted in new problems. The main concern for research funding is the squeeze on public spending. Other policy issues may also be important. For example, the deterioration of the agricultural education establishment in many countries is itself a long-term threat to the ability of these countries to meet the scientific challenges that confront them.

What will be the impact of these policies on the prospects for continued or even increased funding for domestic agricultural research? Certainly this will depend partly on the sense of urgency domestic decision makers attach to the problem. They, in turn, will look to the credibility of the national agricultural research system to demonstrate the relevance of its endeavors and its effectiveness in contributing to national agricultural development.

To a great extent, donors can help encourage and foster credibility of the NARS. Most World-Bank-supported projects have sought to establish an autonomous organizational structure for research under which the NARS is able to provide incentives, career structures, and public recognition independent of the civil service administration. Donors need to give more emphasis, perhaps through in-kind contributions, to the technical assistance and management expertise that will aid these NARS in developing long-term sustainable programs and objectives. In fact, institution-building assistance may be a better investment than was so much of the past assistance in buildings and equipment.

### *The international research system*

The NARS currently depend on the international agricultural research centers (IARCs) for plant genetic material and technical support as well as training opportunities. The broadening of the CGIAR network to include broader commodity coverage will certainly help to expand the pool of knowledge readily available to the NARS, and the international information exchange being developed among the centers (both national and international) will lead to better decisions regarding planning, programming, and budgeting. But what are the prospects for continued funding of international research?

The answer to this question may be somewhat discouraging, particularly if we look at recent trends. There is really very little scope for significant increases in the multilateral aid budget. Both the private for-profit sector and the private nonprofit organizations (for example, the Ford and Rockefeller Foundations) have in the past been, and continue to be, sources of limited assistance to international agricultural research. Bilateral assistance budgets can and should be tapped more than they have been in the past, but certain conditions must be met to maximize support from these sources. Officials in developing countries themselves must be convinced of the value of agricultural research. Perhaps this can best be accomplished by more clearly defining what we believe should be the role of the IARCs and the NARS in a "new international agricultural research order."

Multilateral assistance should continue to fund the international centers, but with the understanding that the activities funded be restricted to those that have a uniquely international character, either because of economies of scale or because of unique benefits captured as a result of international cooperation or organization. The NARS, as well as regional organizations, such as those sponsored by the Special Programme for African Agricultural Research (SPAAR), should be funded through bilateral aid coordinated through international networks. The programs funded in this way would have a national or regional focus and would involve the IARCs as needed.

The international donor community should encourage the creation of these multinational networks, as they have done with SPAAR, which aims at coordinating donor activities in a given area, fostering regional research efforts, and providing adequate funds, not just for initiating, but for sustaining the Programme over the long run. Regional cooperative efforts like this make particular sense in the context of aggregations of countries so small or poor that they cannot establish a viable research administration just for agriculture.

The developing countries are especially fearful of the impact of competing demands for funds and technical assistance from Eastern Europe, just as the agriculture sector has feared a siphoning of precious funds away from agriculture towards the health, education, and infrastructure sectors. Perhaps this is an incorrect approach. For while it is true that they compete for limited resources, it has also been observed that productivity growth and technology adoption occur more readily where there is public investment in infrastructure, education, and health. Indeed, private investment more readily follows well-grounded and sustained public investment.

As for the research systems in Eastern Europe, they are already well developed and connected to the international network, and they require funds mainly for equipment and modernization. In fact, it is quite likely that they will make a net contribution to the international network once they become more active participants.

### *The private sector in research*

One great gap in our information concerning agricultural research is knowledge of what the private sector will and won't do in developing countries. What we can observe is that the public sector tends to do more of the basic research, such as genetics and breeding, while the private sector carries out more applied research. Private research tends to be carried out by multinational rather than domestic firms. The private sector is likely to concentrate on the more profitable and less risky ventures, especially regarding the commercial crops (e.g., cotton, rubber, or palm oil), or in the area of biotechnology. This suggests that the national public sector may be needed to focus on the less-favorable areas, on "orphan" commodities, and to adapt and continue the basic research begun at the IARCs.

Donors must seek to determine which activities require the continuation of public support and which should be left to the private for-profit sector. Private-sector investment requires a favorable policy environment (in such areas as property rights, marketing, and price structure) which enhances rather than penalizes private-sector activity. As Krueger, Schiff, and Valdes (1988) found that economy-wide (indirect) policies tend to have a negative effect on incentives to produce, either directly through price supports or border protection, or indirectly through exchange rate and "infant-industry" policies, so too will these "incorrect" policies negatively affect private-sector agricultural research activity.

The future of the current GATT round of trade negotiations may well help determine the prospect for increased private-sector investment in agricultural research and agricultural activity in general. There is ample evidence that with fewer restrictions on trade, the private sector has greater incentives to find a niche, and that with the prospects for trade, research and development as a component of the total decision to invest will be funded. However, so long as agricultural trade is dominated by the cumbersome bureaucratic national and allied policies we have today, the incentive to invest will be far less. The lack of patent protection is a major disincentive for private-sector investments in developing countries, although some feel that such laws are likely to stifle growth in the research and development sector by adding bureaucratic layers without the requisite trained manpower and special institutes.

## Conclusion

In summary, we have presented what we believe to be the impact of various national and international developments on both the demand for research output and on the supply of resources to agricultural research. To meet the demand for output, research aimed at increasing productivity will also need to address the management of natural resources in order to ensure the sustainability of the productivity gains over the long run, and to broaden its approach by incorporating other aspects of agricultural development, such as marketing and processing channels, nutritional requirements, and other links in the food chain.

However, the current economic and policy environment is such that agricultural research must compete for limited financial resources, available from the international (both multi- and bilateral) aid budgets, domestic budgetary allocations, and the private sector. The agricultural research organizations will have to convince policymakers of the value of research, and this will only be possible if the global research system itself takes responsibility for streamlining its response and output and produces results that are proven to be both efficient and effective in addressing the needs of the global agriculture community.

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# The Role of Research Facing the Global Agricultural Challenge: The View from a National Agricultural Research System

Keynote Address by
*The Honorable Dr. Sjarifuddin Baharsjah*
Junior Minister of Agriculture, Republic of Indonesia

I am very pleased to be here with you today. As a practitioner in agriculture development, I consider the convening of this seminar to be timely. Of late we have observed a number of emerging issues in world agriculture, either as a consequence of developments in the global economy, or as sector-specific policies in response to natural events.

In discussing global agriculture, I would like to share five general points with you: (1) economic globalization, (2) sustainable agriculture and poverty alleviation, (3) decreasing stock of natural resources, (4) declining primary commodity prices, and (5) privatization of agricultural research. In drawing implications, I will try to treat all of these issues from a developing-country perspective.

## Globalization of the World Economy with Special Emphasis on Agriculture

Breakthroughs in communications technology, particularly in fiber optics, have rendered the transmission of information across national frontiers almost effortless. It has vastly facilitated the internationalization of capital and commodity markets and provided a great boost to trade in goods and services. The apparent failure of command systems in meeting the demands of the populace at large have placed the market in the forefront of almost all national economic systems. Capitalizing upon this development, transnational enterprises have also contributed to enhancing the evolution, or revolution, towards a truly global economy.

The trends in global agriculture, to some extent, correspond to those observed in the world economy. The performance of the agricultural sector in developing and industrialized economies has diverged sharply. Agriculture in industrialized economies, evolving from a resource-based to a science-based industry, has witnessed a remarkable growth in productivity (Hayami and Ruttan 1985). In this respect, the European Community (EC) serves as the classical example: its market share of agricultural exports increased from 9.6% in 1973 to more than 12% in 1985 (Koester and Bale 1990). There is no doubt, however, that the protectionist programs espoused under the Common Agricultural Policy have had a major role to play in this.

Policies in a number of developing countries, however, have been biased against agriculture (Krueger, Schiff, and Valdes 1988), primarily for foreign-exchange generation, denoting a proclivity towards industrial development. Confronted with protection and subsidization by OECD members, the share of agricultural exports from developing countries has continued to decline since the early fifties. Even though everyone would agree with Zietz and Valdes (1988) that under a freer multilateral trading system, developing countries gaining better access to markets in industrialized economies will stimulate overall growth in agriculture, the Uruguay Round is still in the doldrums. Should the Director General's text be accepted by the contracting parties, the prospects for healthy growth in agricultural trade and development will certainly be brighter.

The last part of a global trend concerns the role of agriculture in national economies. As structural transformation continues, the role of agriculture seems to decline. In Indonesia, for instance, the share of agriculture in total gross domestic product (GDP) has declined from 40% in 1971 to 21% in 1989. However, in the Indonesian case, the role of agriculture in generating employment is still significant. The share of the sector in total labor employed has only declined from 67% in 1971 to 55% in 1990. Similar phenomena may also be seen in other Asian countries. The large number of households in the agricultural sector demands that its productivity must continue to be enhanced through investments in research and human resources.

## Sustainable Agriculture and Poverty Alleviation

In general, the overexploitation of resources in agriculture has led to environmental degradation: soil erosion, the greenhouse effect, and decreasing biodiversity. Various practices and trends threaten individual ecosystems. Deforestation in the uplands and improper water management in the lowlands are the two major causes of degradation. Methane gas released from rice paddies, carbon dioxide, and other gaseous emissions from the industrial sector contribute to the infamous greenhouse effect.

Aside from the need to generate cleaner technology, we feel that any effective attempt at creating sustainable agriculture over the long run needs to devote adequate attention to all three aspects of growth, sustainability, and poverty alleviation. If we neglect one aspect, we risk jeopardizing the whole effort.

## The Decreasing Availability of Natural Resources

The depletion of natural resources has at least three causes: (1) the intensified use of nonrenewable resources in agricultural production, (2) the increasing competition between agriculture and other sectors in utilizing resources, (3) resource deterioration from pollution and erosion. Four types of natural resources are of major concern, and in what follows we review the trend in the availability of land, water, energy, and biological resources.

### *Land resources*

Data cited by Brown (1991) showed that the per capita grain land is expected to decline from 0.13 ha in 1990 to 0.11 ha in 2000. Growing population pressure, coupled with the expanding industrial sector, exacerbates competition between agriculture and nonagricultural land use. As a consequence of market dynamics, agriculture has been pushed away from high-quality land in the proximity of urban areas to frequently marginal land in more remote areas. In addition to availability, the quality of the remaining agricultural land will itself emerge as a major issue, primarily because of soil erosion. Pari passu with the pushing of agriculture onto marginal lands, there will emerge a need to generate agricultural technology more in line with the new environment.

### *Water resources*

Brown (1991) estimates that per capita irrigated land will decrease from 0.045 ha in 1990 to 0.04 ha in 2000. Improper management of catchment areas might increase the probability of floods and drought, engendering greater instability in agricultural production. In addition to the depletion of water resources, degradation of water quality will be another emerging concern.

These problems require research on (1) new less-water-dependent crop varieties, (2) crop and water management to enhance utilization efficiency, and (3) watershed management.

### *Energy resources*

Fossil fuel supplies will be declining rapidly because of the world's increasing energy consumption, particularly in the developed countries. Increasing scarcity will be reflected in rising prices, which in turn will be exacerbated by rising production costs.

Research into fertilizer efficiency and integrated pest management present two avenues for optimizing energy use in agriculture. Solar and wind energy are major candidates for the substitution of fuel energy. Research into biogas is another avenue worth pursuing, especially in the rural areas. In addition, research into integrated farming systems allowing the recycling of energy within systems (human, animal, fish, and crop energy cycle) is yet another promising area.

### *Biodiversity resources*

Our biological resources are also threatened by both agricultural and non-agricultural exploitation. Land degradation, forest exploitation, coastal development, and environmental stress (such as acid rain) have accelerated the extinction of plant and animal species. Some species are also losing their distinctive characteristics, irreversibly, in response to the changing environment.

While we are losing valuable biotic resources, many of the already-known species are not being fully utilized as alternative sources of food or for other needs. The available inventory of living organisms is also far from complete: some scientists estimate that about five to ten million species remain undescribed (Wolf 1985).

## Declining Prices of Primary Products

In the aggregate, the prices of non-oil primary commodities relative to those of manufactured products declined at 0.59% per year in 1900-1986 (Grilli and Young 1988). This means that the increase of primary product prices has been much lower than that of manufactured goods. With respect to agricultural commodities, relative prices of food products have declined at a lower rate (0.36% per year), compared to those of nonfood agricultural products (0.82% per year).

The primary reasons behind this trend stem from at least three forces: (1) technological advancement in agriculture has raised productivity very rapidly, for instance, average rice yield in the world increased from 2.15 tonnes per hectare in 1965-1969 to 3.33 tonnes per hectare in 1985-1989; (2) there has been a downward shift in the demand for raw materials in manufacturing as a result of the substitution of synthetic products for primary products and advances in technology which have reduced the use of raw materials per unit of final product; and (3) protectionist policies in some countries have led to the accumulation of surpluses, which are then disposed of at greatly subsidized prices.

Such tendencies serve as disincentives to agriculture in developing countries. In the long run, the composition of developing-country exports should include greater processed and semiprocessed content. The scope of the problem is indicated by the fact that the share of developing countries in developed countries' consumption of processed food is just slightly over two percent (Ali 1990).

Placing agroindustry on a sound footing requires adequate research into areas like product development, designing appropriate machinery, and formulating policies to create a conducive business climate.

## Privatization of Research

The application of advanced science and modern technology will become a major characteristic of agriculture of the future. The advancement of biotechnology, for example, has opened a new frontier of agricultural systems that will not only affect agricultural production but will also be affected by the structure of intellectual property rights.

In economic terms, the granting of intellectual property rights to researchers means acknowledging that they have monopoly power over their product. However, resolution of the right of ownership here is not as forthright as in other areas. Because agricultural production is a biological process controlled by DNA, product variety is inherently a characteristic of agricultural production. Variation is also a function of time: there is a process of coevolution that changes biological structure on its own. As a consequence, applying patents to intellectual products in agriculture is limited by processes inherent in biological production.

There is a prima facie case for greater collaboration between national governments and IARCs in assuring that privatization leads to benefits for scientists, farmers, and consumers alike.

## General Perspectives of Developing Countries

Thus far we have outlined the present and emerging issues facing global agriculture. Based on this, we now briefly discuss the direction in which agriculture should proceed and identify research areas requiring greater emphasis. In so doing, it is assumed that all the necessary preconditions are met, although we recognize that some peculiar characteristics of developing countries may act as binding restraints.

The fundamental issue in developing countries is poverty alleviation. Because of widespread poverty, meeting subsistence needs — particularly food needs — is still a major concern. It is understandable, then, that producing sufficient food will remain a primary national objective in agricultural development, placing considerable pressure upon natural resources.

Pressures are further exacerbated by the fact that farms in developing countries are relatively minute, and farm size is decreasing even further under intensifying population pressure. In addition to low physical capital, the acquisition of educated human capital is also low.

Although increasing food production requires the continuous effort of the developing countries, agricultural diversification has also received more attention. This strategy is needed to meet the broader needs of the population, to create a much more balanced agricultural base, to expand employment opportunities, and to help conserve natural resources.

## Implications for NARS

It is thus apparent that the national agricultural research systems have a full research agenda, if the aforementioned issues are to be adequately addressed. Some of the issues are global in nature; accordingly, they must be addressed globally. Global warming and the attendant greenhouse effect is one such phenomenon, as is the maintenance of biodiversity. Agricultural sustainability and poverty alleviation oftentimes involve efforts to ensure that resource-poor households are not deprived of their traditional access to local markets, in the face of external pressures upon rural communities. Policies aimed at mitigating the adverse effects of declining commodity prices constitute the major concern of developing-country governments.

The agenda calls for the NARS to interface effectively with institutions at all levels. They must tap into the network of international agricultural research centers to deal with the global issues, strike a strategic alliance with their respective governments in formulating effective development policies, and enter into truly collaborative efforts with regional universities to meet local needs. At the same time, the NARS must establish symbiotic relationships with their fledgling agribusiness, so that both can continue to develop in tandem. Unless the traditional sources of funding are augmented by private resources, the NARS may experience major difficulties in retaining their highly trained human capital.

## Concluding Remarks

This paper highlights a number of fundamental issues that are finding currency in global agriculture. Research has an important role in responding to these emerging issues. However, it should be borne in mind that the capabilities of individual national agricultural research across nations is quite disparate. This stems from differences in resource endowments, stage of development, and the individual policy environment.

In view of the above observations, collaboration across NARS should be intensified. By doing so, spillover effects of the research output from a specific country can be maximized and the capacity of NARS strengthened. It would be within ISNAR's mandate to promote such cooperation.

In light of national budgetary constraints, the international agriculture research system should try to maximize the spillover effects of their research. This can be achieved, for instance, by conducting more outreach programs to disseminate research results in the relevant countries.

It is also noted that government policy regarding agricultural research varies from nation to nation. Hence, the system is expected to take part in an effort to convince respective governments of the contribution that appropriate research can make to national development. With strong governmental support, research capabilities of the NARS can be further strengthened.

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# A Policy Perspective on the Sustainability of Production Environments: Toward a Land Theory of Value

*C. Ford Runge*
Center for International Food and Agricultural Policy
Department of Agricultural and Applied Economics
University of Minnesota, USA

## Overview

The growing importance of environmental issues is changing the face of agricultural economics and politics, both domestically and internationally. The national agricultural research systems (NARS) are increasingly affected by the debate over "sustainability." It has become obligatory to gesture to the environment as being of growing importance, but what exactly should be done? What policies can maintain and improve agricultural productivity, while at the same time protecting environmental benefits and minimizing the environmental damages of modern agricultural production methods?

Broadly speaking, in the developed countries it is the commodity composition of agricultural growth, together with the increasing use of water, fertilizer, and chemical inputs in food production, and intensive animal production, which account for most environmental concerns in agriculture. In developing countries it is deforestation and habitat destruction in areas opened to cultivation. Commodity composition refers simply to the mix of farm products produced.

Agricultural production has become increasingly specialized at the farm level since the 1950s, especially in the OECD countries. Specialization due to comparative advantage occurs naturally in the course of agricultural growth and development. But the degree of intensive specialization at the farm level in such crops as maize or cotton, as well as the concentration of livestock production in limited geographic areas, has been driven in many developed countries less by market demand than by domestic and related trade policies that subsidize this narrow production focus directly and indirectly.

The increasing use of chemical inputs has occurred in large part because the demand for them is *derived* from the demand for farm output, whether the demand arises in the market or from government subsidies and purchases. In both developed and developing countries, the crops which governments have subsidized have accounted for the bulk of irrigation, fertilizer, and pesticide applications. In addition to the derived demand for water, fertilizer, and chemicals, many governments have further subsidized the use of these inputs by tax allowances or price markdowns that make them less expensive to use.

Many of these changes in production — especially in developing countries — have been justified as necessary for feeding growing populations or increasing food self-sufficiency as a matter of trade policy and national security. The result has been that adverse environmental consequences have been treated as unfortunate but probably justifiable by-products (externalities) in meeting these challenges. As this perspective changes, especially in the OECD countries, the demand for new environmental regulations will effectively raise the cost of environmentally irresponsible farm production methods, inducing new, more environmentally benign technologies. However, this process is just beginning, and the market and government failures of the post-war period have clearly generated substantial environmental damage. And as long-term population growth continues to require increases in food production, environmental issues in agriculture are likely to remain important.

Farmers in developing countries are typically taxed rather than subsidized, in the form of food prices held below market levels in response to the political influence of urban consumers. While they depress production, these policies do not necessarily conserve natural resources, for two reasons. First, poor farmers are often compelled to farm marginal lands subject to erosion and runoff, or to clear forests that have held soil in place, in order to reach a subsistence level of income. If the household is already operating at or near subsistence, lower prices do not cause reduced output. Second, subsidies are sometimes paid to reduce the costs of farm inputs (fertilizer, pesticides), which leads to overapplication and consequent water and soil contamination. While fertilizer, in particular, has been vital to meeting food demands, many government policies have had untoward effects on the environment. Although insufficient research is available, several studies suggest that the impacts of government policies in developing countries are at least as important as in developed countries, both in distorting markets and harming the environment.

While all of the market failures associated with agriculture in the developed countries are replicated in the developing world, the incapacity of government to intervene effectively to regulate the environment is even more evident. Environmental quality is a "superior good," the demand for which rises increasingly in proportion to increases in income. By contrast, food production is an "inferior good," the demand for which falls in proportion to increases in income (Engels's Law). In the high-income developed countries, for example, regulations affecting pesticide use have become more stringent in the last two decades. Food quality increasingly dominates food quantity as concerns over environmental health and safety grow. In low-income developing countries, by contrast, the political and economic constituency of greatest interest to governments is the urban consumer who demands low prices. Environmental quality has a weaker constituency. Food producers are a large and politically unorganized source of revenues, and are thus generally taxed, in large part by having their product extracted at below-market prices. In partial compensation, input subsidies are paid to increase yields. In some cases these subsidies may be justified to maintain soil fertility through nutrient applications. In other cases, the environmental effects are clearly negative.

Responding to the dual challenge of agricultural productivity gains *and* environmental protection requires more carefully targeted and articulated policies at three levels. The first is at the national and multinational levels: the agricultural and environmental policies of the OECD nations and developing countries. The second is at the farm level, where technological and environmental choices are ultimately made. The third is at the level of agricultural research policy, which will guide the long-run choices of national policymakers and individual producers.

While this brief paper cannot provide detailed policy recommendations, the perspective developed points in the following directions (for a detailed analysis, see Runge 1991 and Cochrane and Runge 1992). At the *national* and *multinational* levels, agricultural policies should incorporate environmental objectives explicitly. Traditional agricultural policies promoting commodity-specific increases in output should be replaced with "decoupled" policies combined with incentives to farm less intensively lands that are highly vulnerable to environmental damage. A system of financial penalties should be applied to damaging environmental practices, and a system of rewards for environmental "affirmative actions."

At the *farm* level, implementing these policies will require more-clearly targeted approaches to lands according to their agronomic characteristics, including potential productivity and vulnerability to environmental damage. On productive lands vulnerable to such damage, "precision farming" methods will be at a premium (Munson and Runge 1990). Farmers should be encouraged to adopt these technologies on vulnerable land areas, but should not be discouraged from yield goals on productive land with low levels of environmental vulnerability.

At the level of *research policy*, the "mix" of environmental and yield-increasing agricultural research will depend on the types of land and landscapes in question, and the different weight attached to environmental quality versus food production, especially in the North versus the South.

The context in which these policy prescriptions emerge is a view of the sustainability debate as an outgrowth of conflicts between two research agendas. The first is the traditional commodity-oriented agenda that has dominated the NARS from their origins. The second is an environmental or "green" research agenda. Sustainability reflects the conflicts between these agendas, but also offers opportunities for a synthesis. Defining such a synthesis, and the policies that should underlie it, is the primary objective of this paper.

The paper is divided into four parts. Part one provides a basic description of the agricultural production process as a dynamic flow, producing not only commodities but environmental "goods" and "bads" (damages) as well. Part two discusses the research agendas that have influenced this production process and the conflicts between traditional commodity-oriented research and the newer environmental research agenda. Part three takes up the common ground uniting these two agendas: a concern for the uses of land and the effects of this use on both commodity and environmental flows. Part four offers some specific recommendations for reforms in land policy and targeting at the national level and the farm level and the implications of these reforms for agricultural research systems.

## Agricultural Production as a Process

Agricultural policy, and research, continue to focus on an optimal set of partially hydrocarbon-based inputs — labor, capital, energy, nutrients, chemicals, and water — in combination with land to produce various types of foods, feeds, and fibers. Naturally, the cost of these inputs varies greatly from time to time and place to place, giving rise to efforts to overcome constraints on their availability through technological and institutional innovations. This process of induced innovation has exercised an important guiding influence on the NARS and their missions (see Pardey, Roseboom, and Anderson 1991 and Ruttan 1992). In particular, it has led to a conviction that agricultural production paths can be "designed" through policies affecting the supply and demand for agricultural inputs and outputs (figure 1).

However, some inputs (e.g., hydrocarbon-based energy) are limited not only locally but globally, and not all of the outputs of this process have been given full weight. Specifically, land produces not only flows of commodities, including foods, feeds, and fiber, but other streams of products. One such product is environmental amenities, such as landscape quality, wildlife habitat, groundwater recharge, and recreation opportunities. Another is environmental damages such as water pollution, resulting in large part from intensive use of energy-based plant nutrients. These flows of environmental

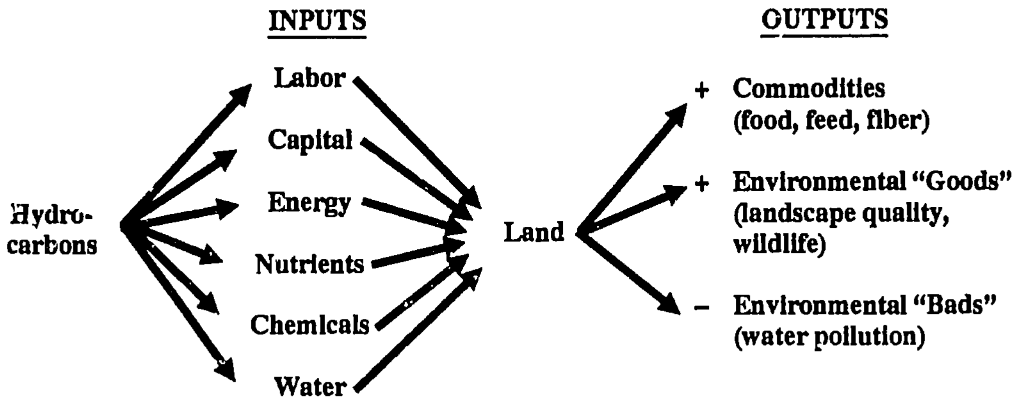


**Figure 1.**
**Production flows in agriculture**

"goods" and "bads" have not had high political value nor have they been reflected in market demand for much of agricultural history. But a new era is dawning, in which public demands for both environmental goods and reductions in environmental bads increasingly dominate political and economic discussions. As a result of the implicit value given to the environmental aspects of land and its production, the process of technological and institutional innovation is being given new "inducements," of which this conference is an example (see Runge 1987).

However, the paths of technological and institutional change taken in response to these pressures are by no means uniform. In particular, there are major differences in the apparent "weight" attached to traditional agricultural commodities versus environmental goods and bads in the North and South (Runge 1990). This North-South gap poses a special challenge for those who assert that "sustainability" is of equal importance to all nations and suggests one of the many senses in which assertions of sustainability as a covering concept for policy are "not enough" (Ruttan 1988; Graham-Tomasi 1991). I will return to this issue at the conclusion of this paper.

## Research Agendas in Conflict: What Synthesis is Possible?

The conflict between traditional commodity-oriented agricultural research and the new agenda of environmentally oriented research is much noted (e.g., Norgaard 1991; Batie 1989). It may be useful, therefore, to characterize the differences in emphasis of the two streams of thought. I will call them "environmental research" and "agricultural research" (figure 2).

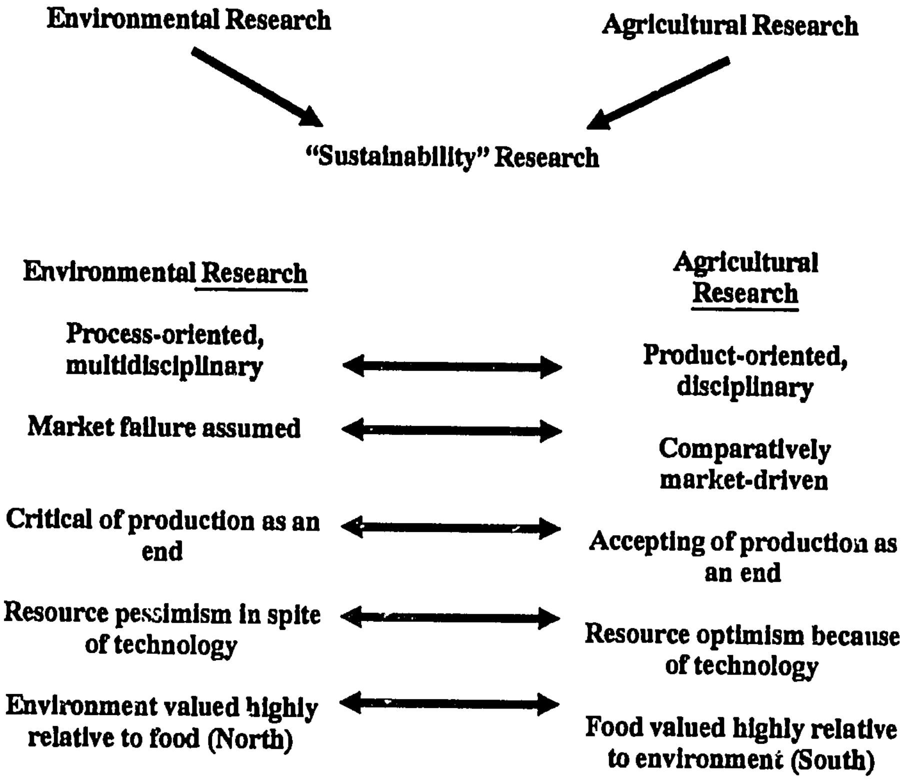


**Figure 2.**
**Conflicting research agendas**

Environmental research, at least in agricultural economics and the applied agricultural sciences, has had the following general characteristics.

1. It is process oriented, in that it focuses on the flow of various damages, such as nitrate pollution through the agricultural production system and into waterways.

2. It is conducted on the general assumption that market signals are insufficiently strong to guide decisions by farmers; such "market failure" creates a presumptive role for regulation.

3. It is largely critical of analysis that views increased production (yields) and aggregate growth as ends in themselves.

4. It assumes that the relative scarcity of natural resources in the face of population growth, even with technological change, is likely to be binding over time, promoting "resource pessimism."

5. It places an implicit value on improvements in environmental quality, reflecting the income-driven valuations of high-income developed countries.

In contrast, the traditional agricultural research of the NARS has had the following general characteristics.

1. It is product oriented, focusing on specific commodities and disciplinary attempts to develop more efficient, or robust, varieties of these commodities in different agroenvironmental settings.

2. It is comparatively market driven, giving value primarily to those commodities in greatest demand.

3. It sees increased production (yields) and growth as legitimate ends in themselves.

4. It is dominated by an optimistic view of natural-resource systems in agriculture as manipulable through technological change, so that a Malthusian collision between population and resources can be avoided.

5. It places greatest emphasis on food and fiber production and the provision of those commodities to low-income groups, notably in developing countries.

Even if these contradictions are only approximately accurate, they suggest that the two agendas are not likely to be combined without conflict. Nonetheless, I submit that a new synthesis is emerging.

## Sustainability as a Synthesis

A compromise of two differing agendas is unlikely to be neat and orderly, as framers of legislation in democracies know. That is why definitions of sustainability are either excessively qualified or overly general in focus: they need to be, in order to reflect the differences of the two agendas above. But, in practical terms, this does not detract from the utility of pursuing synthesis through compromise, any more than differences of opinion among democratic leaders imply the inutility of final agreements. It will be recalled that figure 1 illustrated the central role played by land as a factor of production, whether from a strictly commodity-based or more environmental perspective. Along each of the five lines discussed above, I would argue that a new synthesis is now emerging, based on altered considerations of land use. In this sense sustainability is almost a restatement of physiocracy, a "land theory of value" (figure 3).

First, the commodity and disciplinary emphasis of agricultural research is

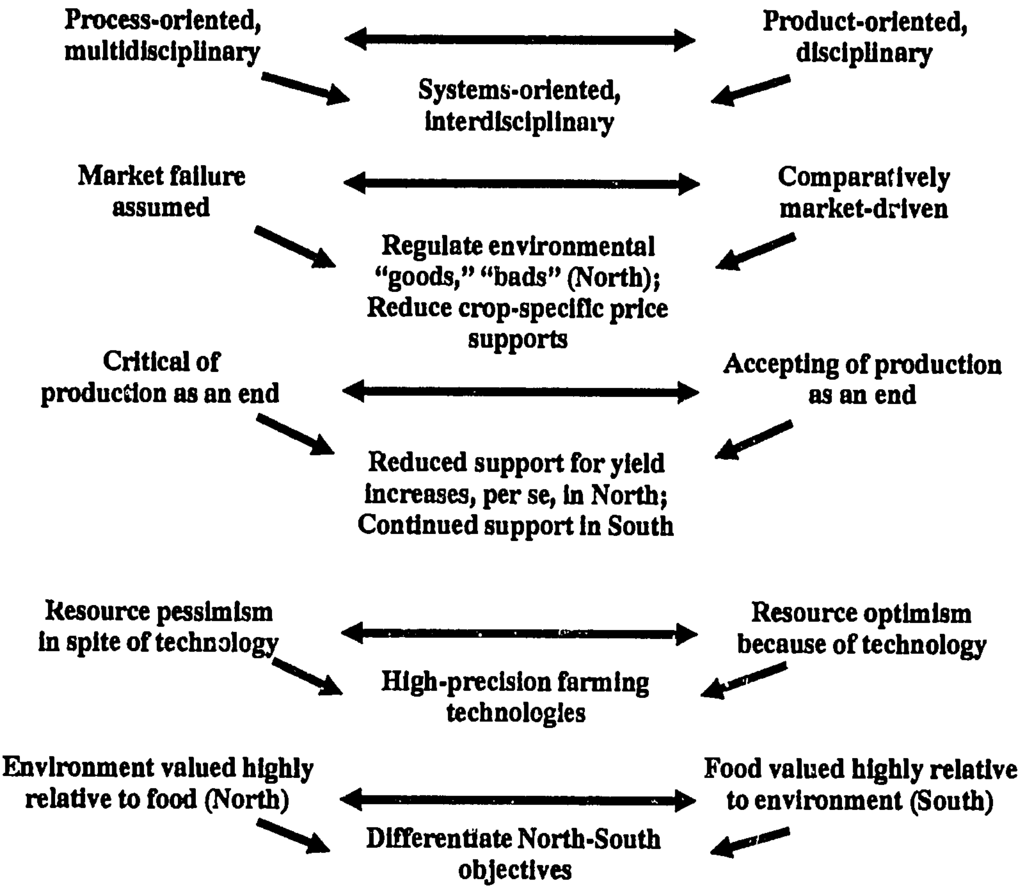


**Figure 3.**
**Sustainability as synthesis**

giving way to "systems" approaches with an interdisciplinary emphasis. This change in emphasis is linked to, and will be enhanced by, movements at the level of policy away from commodity-specific farm-income support and in the direction of a decoupled system of land- and landscape-based agricultural subsidies and penalties. These subsidies and penalties will reward farmers for land-conserving practices and penalize them for damage.

Second, the growing public demands in the "political marketplace" of high-income countries for environmental "goods," such as landscape quality, and reductions in environmental "bads," such as water pollution, are creating a stronger presumption in favor of regulating agricultural land use to achieve environmental objectives. On the other hand, government interventions designed simply to enhance output are falling from favor because of chronic surpluses. These changes will create new incentives to alter the mix of commodities produced on agricultural land and the way in which they are produced. However, the "political marketplace" is sending different signals in the developing countries, where food and fiber production continue to prevail over environmental concerns.

Third, and related to the above, is a decreasing enthusiasm for yield-increasing technologies, per se, in the North but a continuing emphasis on the need for such technologies in the South.

Fourth, the resource pessimism of the environmental agenda is challenged by the success to date of agricultural technology in overcoming widespread starvation. However, the imperative to continue increases in yield and output is being combined with attention to environmental effects to generate a new round of technological innovations which we have called "high-precision farming" technologies (Munson and Runge 1990). The role of research in advancing these technologies may depend on institutional innovations that support them.

Fifth, and perhaps most significant for the NARS, is the challenge of differentiating the research agendas relevant to North and South. Here the lessons of the induced-innovation hypothesis reinforce the notion of different paths of technological change and land use, in which the tolerance for environmental damages may differ. But in an integrated world economy, such divergent parties create problems of trade conflict over environmental barriers (Runge 1991).

Thus, the emerging synthesis is generating new conflicts, to which innovators of technology and institutions must creatively respond. What should some of these policy responses be?

## Policy and Sustainability

If the centrality of land use is accepted as a basis for thinking about the sustainability of production environments, how might we target different land categories in terms of policy intervention? Consider the typology below, depicting differences in a land area (including watersheds) in terms of vulnerability to environmental damage (e.g., soil erosion, water pollution) and potential productivity (figure 4). Note that the level of aggregation of the land parcel is, for present purposes, arbitrary: it could be a single farm, a region, or an entire nation. Note further that we describe land use as the center of a production system, not simply as a parcel of soil.

In the upper left-hand corner are lands that are low in productivity potential and relatively low in vulnerability to environmental damage. These highly marginal lands are neither candidates for policy interventions to promote production nor are they likely to reward investments in agricultural or

AGRICULTURAL LAND AREAS

| Productivity potential | | Vulnerability to environmental damage: Low | Vulnerability to environmental damage: High |
|---|---|---|---|
| | Low | Low policy intervention | Policy promoting "high-precision farming" |
| | | Low research priority | "Sustainability" research |
| | High | Yield-promoting policies | Penalties for damages |
| | | Yield-promoting agricultural research | Environmental research |

**Figure 4.**
**A typology of land-use, policy, and research needs**

environmental research. In the upper right are those lands that remain low in productivity potential but are highly vulnerable to environmental damage. Here environmental agencies must take the lead to create disincentives, such as fees or penalties, to discourage agricultural production. Research on these lands should be directed toward environmental objectives, not agricultural ones. In the lower left are high-productivity-potential lands with low environmental vulnerability. Here traditional yield-increasing incentives and research directed toward traditional agricultural objectives will have the highest payoff.

Finally, and of greatest relevance to sustainability issues, is the lower right quadrant, where high productivity potential is combined with high vulnerability to creating major environmental damage from agriculture. It is on these lands that a synthetic approach, combining yield-enhancing technologies with high-precision methods, is most needed and where the synthesis of environmental and agricultural research, or "sustainability research," is most relevant. Now consider the specific implications of this perspective for policy reforms at various levels. At the national and multinational levels, policies that continue to reward the production of specific commodities, irrespective of the land category on which they are produced, will tend to promote inappropriate production patterns with adverse environmental effects. Agricultural policies of "decoupling," in contrast, will allow more diverse cropping mixes, but in themselves they will not promote environmental objectives unless they are combined with appropriate environmental policies to encourage landscape quality and discourage agricultural production on vulnerable land areas. This implies both fees and penalties on vulnerable lands, and subsidies for environmental improvements.

At the farm level, production on high-productivity and low-vulnerability land areas should be encouraged. Where lands highly vulnerable to environmental damage are in production, farmers should be encouraged to employ high-precision methods that minimize damage over time. These methods can take many different forms and are discussed in detail elsewhere (Munson and Runge 1990).

Finally, at the level of research policy, a clearer delineation of research directed toward environmental objectives or toward agricultural production should be made. For many land areas, traditional agricultural research will continue to have relevance, but where lands are vulnerable to environmental damage, more systems-oriented, interdisciplinary research, emphasizing the trade-offs between increased yields and environmental damage along with development of high-precision technologies, will come into play.

Since the proportion of land falling into each category, and the importance attached to environmental vulnerability itself, varies greatly, it follows that the policies, farm practices, and relevance of research results will also vary considerably from nation to nation, region to region, and even farm to farm. Most significant, the relative difference in these qualities between North and South suggests that sustainability is, and probably ought to remain, a mutable concept.

It is very difficult to envision a single research agenda based on sustainability that unites the objectives of the food systems of North and South, except insofar as land use becomes a unifying theme. Land use (and misuse) provides a general basis on which agricultural production and productivity gains can be considered at the same time as reductions in the intensity of production on lands most vulnerable to environmental damage. We are increasingly able to use modern technologies — to differentiate such lands and to apply more precise agricultural techniques to them. What is lacking is an institutional commitment to develop incentives for changes in national, farm-level and research-system behavior consistent with our renewed awareness of the centrality of land in agricultural and environmental flows.

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# NARS Trends and the Structure of Support

*Philip G. Pardey*
Senior Officer
ISNAR

As we approach the end of the 20th century, policymakers are having to contend with unprecedentedly rapid changes in the market for agricultural science and technology services. In the less-developed countries, the rapid expansion of public agricultural research capacity experienced during the 1960s and 1970s slowed considerably in the 1980s. Particularly in debt-ridden regions like sub-Saharan Africa and Latin America & the Caribbean, investment in agricultural research stagnated or even declined. In addition, the level of development aid to less-developed countries stalled during the 1980s, while the small but significant share that was channeled to agricultural research has been threatened by other demands.

A reversal of these trends is unlikely in the near future and, therefore, resources for public agricultural research in less-developed countries could well tighten even further in the coming years. In the more-developed countries, public support for agricultural research is under close review, and there is a strong tendency to have those who most directly benefit from research pick up at least part of the bill. Moreover, agricultural surpluses, declining agricultural prices, and continuing declines in farm numbers in many of the more-developed countries have led to populist calls for a moratorium on further public investment in agricultural research.

Against this backdrop of fiscal stringencies, the demands being placed on national, and indeed international, research systems are intensifying. In addition to the traditional emphasis on stimulating productivity growth within agriculture, many of these systems are also being called upon to broaden their research agendas and give greater attention to concerns of environmental degradation and resource management. The international system is also restructuring its research portfolio with regard to forestry, fisheries, and vegetable research, in addition to its traditional emphasis on basic food crops and livestock. These changes raise major policy issues about the appropriate division of labor and problem focus between the national, regional, and international centers that are yet to be resolved.

Furthermore, the modern biotechnologies based on recombinant DNA, monoclonal antibodies, and new cell- and tissue-culture techniques are just beginning, and no doubt will continue, to fundamentally reshape the science of agriculture well into the 21st century. When taken in conjunction with the increasing propensity of governments to enact and enforce legislation on intellectual property rights (including plant variety protection acts), these new technologies raise a further set of policy concerns related to the optimal division of labor and effort between publicly versus privately executed research.

Within the context of these issues, what follows is a brief quantitative overview of the development of national agricultural research capacity over the past quarter century. Special attention will be paid to the level and structure of support for the NARS of less-developed countries.

## Investments in Public Agricultural Research

For two decades — up to the mid-1980s — global investment in public agricultural research increased substantially. Over this period there was a 2.6-fold increase in global expenditure on public-sector agricultural research and a 2.2-fold increase in research personnel. By 1981-85 around 134,000 full-time- equivalent researchers were working in public-sector agricultural research and spending annually just over $8.4 billion 1980 dollars.

The number of researchers in less-developed countries increased by 7.1% a year, just over four times the annual rate in more-developed countries (table 1). So, by 1981-85 the less-developed countries employed 58% of the world's agricultural researchers, compared with 33% in 1961-65.

Annual growth rates in research investment in less-developed countries have slowed during the 1980s, most noticeably in sub-Saharan Africa and Latin America & Caribbean, both of which have been struggling to contain soaring international debts. Although spending on agricultural research increased faster in less-developed than in more-developed countries during the past two decades, the less-developed countries' share of total expenditure on research rose only to 43% from 33% in 1961-65.

Of the less-developed regions, only in Asia & Pacific did annual growth in research expenditure exceed the annual increase in researchers. In more-developed countries, on the other hand, spending on research increased twice as fast as the number of researchers.

## Expenditures per Researcher

Average spending per researcher in less-developed countries has been falling since the early 1970s. In 1981-85 it was actually lower in real terms than

**Table 1. Annual Agricultural Research Personnel and Expenditures — Regional Totals**

| Region | 1961-65 | 1971-75 | 1981-85 | Growth rate[a] |
|---|---|---|---|---|
| | *Agricultural research personnel (full-time equivalents)* | | | % |
| Sub-Saharan Africa (43)[b] | 1,300 | 2,400 | 4,900 | 6.8 |
| China | 7,000 | 11,600 | 32,200 | 8.0 |
| Asia & Pacific, excl. China (28) | 6,600 | 12,400 | 22,600 | 6.3 |
| Latin America & Caribbean (38) | 2,700 | 5,800 | 9,000 | 6.3 |
| West Asia & North Africa (20) | 2,200 | 4,700 | 9,000 | 7.4 |
| Less-Developed Countries (130) | 19,800 | 37,000 | 77,700 | 7.1 |
| More-Developed Countries (22) | 40,400 | 48,100 | 56,400 | 1.7 |
| Total (152) | 60,100 | 85,100 | 134,100 | 4.1 |
| | *Agricultural research expenditures (millions 1980 dollars)* | | | |
| Sub-Saharan Africa (43)[b] | 149.5 | 276.9 | 372.3 | 4.7 |
| China | 271.4 | 485.4 | 933.7 | 6.4 |
| Asia & Pacific, excl. China (28) | 316.7 | 651.5 | 1,159.6 | 6.7 |
| Latin America & Caribbean (38) | 229.1 | 486.6 | 708.8 | 5.8 |
| West Asia & North Africa (20) | 126.9 | 300.8 | 455.4 | 6.6 |
| Less-Developed Countries (130) | 1,093.6 | 2,201.0 | 3,629.8 | 6.2 |
| More-Developed Countries (22) | 2,190.7 | 3,726.3 | 4,812.9 | 4.0 |
| Total (152) | 3,284.3 | 5,927.3 | 8,442.7 | 4.8 |

*Note*: Totals may not add up exactly because of rounding.
a. Compound annual average growth rate between 1961-65 and 1981-85.
b. Bracketed figures indicate the number of countries in the regional totals.

in 1961-65. In more-developed countries, meanwhile, spending per researcher has been rising steadily, and their emphasis has consistently been towards greater investment in human capital within the NARS. As a consequence, spending per researcher in 1981-85 for less-developed-country NARS averaged $59,200 in constant 1980 dollars, compared with $99,100 per researcher in the US.

One reason for the relatively lower spending per researcher in less-developed countries is that, of late, the rapidly expanding university systems in these countries have produced many more graduates than previously. Many governments in less-developed countries require that public bodies, including research systems, employ local graduates, but then they fail to provide adequate matching funds.

In China and the Asia & Pacific region, expenditure per researcher has always been lower than in other less-developed regions. This is partly because relative prices for labor are lower, which induces a substitution of labor for other inputs in the system. But it is also because they have predominantly larger research systems that may well be able to realize economies of scale and scope.

In sub-Saharan Africa, expenditure per researcher has for a long time been higher than in other regions. During the 1960s, the NARS in this region continued to be heavily staffed by relatively expensive expatriates from the former colonial powers. The poor quality of Africa's infrastructure and the need to import nearly all equipment also drive up the research costs in this region. Although still higher than in most other less-developed regions, spending per researcher in sub-Saharan Africa is falling, in part a reflection of the fact that expatriate researchers are increasingly being replaced by less-expensive local research staff.

## Commodity Orientation

In less-developed countries, agricultural research is directed predominantly at crops. Roughly two-thirds of all agricultural researchers in less-developed countries are engaged in work related to crops. For the remainder, 19% are engaged in livestock research, 7% in forestry research, and 6% in fisheries research.

There are some limited regional disparities in the share of resources devoted to a particular commodity area (table 2). While such disparities are inevitable, given regional variations in the pattern of production, it has been argued that less research is devoted to fisheries and forestry than their reported economic importance warrants. In fact, the data, as shown in table 4, do not generally support this proposition. Research into forestry attracts more resources than its congruent share in agricultural output in all regions. In Asia & Pacific and West Asia & North Africa, this is also true of fisheries.

Nevertheless, the actual facilities for research into forestry and fisheries are limited, primarily because NARS in less-developed countries are generally small. The majority (73%) of them employ fewer than 200 researchers in total, while only small percentages of these are engaged in research into fisheries or forestry.

**Table 2. Regional Congruence between AgGDP and Agricultural Research Personnel**

| Region | Crops & Livestock | | Forestry | | Fisheries | |
|---|---|---|---|---|---|---|
| | AgGDP | Research | AgGDP | Research | AgGDP | Research |
| | % | % | % | % | % | % |
| Sub-Saharan Africa (22)[a] | 88.6 | 87.3 | 4.7 | 7.3 | 6.6 | 5.4 |
| Asia & Pacific, excl. China (10) | 89.7 | 81.1 | 5.2 | 9.4 | 5.0 | 9.6 |
| Latin America & Caribbean (20) | 94.2 | 92.8 | 2.9 | 5.4 | 2.8 | 1.8 |
| West Asia & North Africa (7) | 95.9 | 91.6 | 2.4 | 5.7 | 1.7 | 2.7 |
| Less-Developed Countries (59) | 90.7 | 87.0 | 4.6 | 7.3 | 4.6 | 5.7 |

*Note*: Data may not add up exactly because of rounding.

a. Bracketed figures represent the number of countries included in the regional samples on which the AgGDP breakdown is based.

## Factor Shares

A major challenge for managers of research systems is to make the most effective use of available resources. The best mix of spending on capital equipment, personnel, and operating costs will depend to a large degree on the relative availability and cost of research inputs, their quality, and the type of research being conducted. Since the most effective combination will differ between regions and will change within a system over time, it is unrealistic to propose standards for determining the "optimal" mix of inputs in research. The data presented in this section should be regarded as some order of magnitude based on a sample of countries, not as economic optima to necessarily be targeted.

The available data suggest that in 1981-85, NARS in less-developed countries on average devoted 19% of annual expenditures to capital investment, compared with 8% in the US. The higher share of spending on capital equipment, at least until the mid-1980s, by NARS in less-developed countries supports the conclusion, also evidenced by their rapid growth, that most were in an expansionary phase. During this phase, not only must capital stock be replaced each year, but new capital stock must be purchased.

A second factor in the higher share of capital costs in less-developed-country NARS is that capital items are often relatively more expensive in less-developed countries, and they often lack adequate repair and maintenance facilities, leading to an early equipment write-off. Factor substitution, where less-expensive inputs are substituted for more-expensive inputs, may counterbalance this effect somewhat, but it is not likely that it will outweigh it.

Whereas salaries and operating costs in agricultural research expenditures represent service flows, capital expenditures represent additions to a stock. Thus, the high share of capital in annual spending may also exaggerate the actual share of capital in the services used to perform research. Capital equipment can last for many years, and a measure of service flow, rather than of expenditure, would probably reduce the share of capital actually used by a research system in any given year, particularly if such a system expands rapidly.

The recurrent costs of NARS can be divided between salaries and operating costs. In less-developed countries, salaries tend to be lower and operating costs higher than in more-developed countries. In 1981-85, a sample of 43 less-developed countries on average spent 30% of recurrent expenditures on operating costs, compared with 25% in the US.

One of the major difficulties in making plausible cross-country comparisons of factor shares is that spatial differences in price levels, which are not consistent across different expenditure items, act to confound the comparisons. Thus, if spending on operating costs and salaries is adjusted to take account of price differences between countries, research in less-developed countries is seen to be more labor-intensive relative to the US. Looked at in this way, the share of operating costs in recurrent expenditures in 1981-85 fell to an average of 15% in less-developed countries, compared with the 30% noted earlier.

After adjusting for cross-country price differentials, operating expenditures per researcher are much smaller in less-developed regions than in the US. Agricultural researchers in sub-Saharan Africa, Asia & Pacific, Latin America & Caribbean, and West Asia & North Africa work with only 50%, 43%, 74%, and 22%, respectively, of the operating resources provided to a US researcher. However, the salary component of recurrent expenditures (including the salaries of both scientific and support staff) in the less-developed regions is much closer to the US level. And in sub-Saharan Africa it is even higher. This may be accounted for by the relatively high number of expatriates still working in African NARS and the fact that the employment policies of many governments in less-developed countries result in NARS employing large numbers of support staff.

## Human Capital in Research

One of the fundamental strengths (or, too often, weaknesses) of NARS, and a major factor in determining the success of agricultural research, lies in the quality, composition, and deployment of their research staff.

Developing meaningful measures of this human capital component is challenging, both conceptually and practically. Indicators such as university qualifications and years of research experience may explain much of the difference in quality between research systems, but they are not the only factors. The composition of the research staff will depend, among other things, on the NARS's size and the type of research it is conducting. These influences vary greatly between regions and will change within a system over time. For instance, a smaller NARS whose activities are focused more on capturing research spillovers and adapting them to local circumstances is unlikely to need a cadre of researchers similar to that required by a large NARS that is likely to confront an altogether different scale and set of research problems. Similarly, while a system dominated by researchers holding PhDs and 20 years of experience may be considered highly qualified, it is not necessarily the most appropriate labor force for confronting the applied and site-specific problems that face many national research systems today.

Data for the period 1981-85 indicate that roughly one-half of agricultural researchers, including expatriates, in less-developed countries held a postgraduate degree, either a master's or doctorate. If expatriate researchers are excluded from the calculation, no less-developed region has a share of researchers with a postgraduate qualification greater than 60%, and in a significant number it is lower than 40% (table 3). Among more-developed countries, this proportion appears to be between 70% and 90%. Somewhat surprisingly, poorer less-developed regions have a relatively high proportion of qualified staff, although that is much lower if expatriate researchers are excluded from the calculation.

**Table 3. Nationality and Degree Status of Agricultural Researchers, 1981-85 Average**

| | Expatriates | Share of Postgraduates[a] |
|---|---|---|
| | % | % |
| Sub-Saharan Africa[a] | 29 | 45 |
| Asia & Pacific[b] | 11 | 53 |
| Latin America & Caribbean | 2 | 51 |
| West Asia & North Africa | 18 | 27 |
| Less-Developed Countries[b] | 12 | 48 |
| Australia | na | 57 |
| New Zealand | na | 78 |
| United States | na | 93 |

a. Measures the proportion of national researchers holding a PhD or MSc degree or equivalent. Figures for Australia and New Zealand are for 1981 and for the United States are 1980 only.

b. Does not include China and India, the two major NARSs in Asia.

### *Expatriate researchers*

In many less-developed countries the early agricultural research institutes were established by European colonial powers, and during the first half of this century these institutes were staffed with expatriate researchers. On independence, most former colonies moved to replace expatriates with national researchers. In some countries this change took place gradually, but in others it was a more abrupt process and caused major disruptions in agricultural research programs. At present, only the smaller countries of sub-Saharan Africa, the Caribbean, the Pacific, and the oil-rich countries of West Asia have relatively large proportions of expatriates on their research staffs. The share of expatriates is declining rapidly, however. In sub-Saharan Africa, for example, the share of expatriates in NARS was about 90% in 1960 but had declined to some 30% in the early 1980s.

Making the plausible assumption that the numbers of expatriate researchers working within the Chinese and Indian systems are negligible, the percentage of expatriate researchers working throughout the less-developed world in 1981-85 is estimated to be around 3%.

### *Optimum composition of staff*

Although economic development can be expected to increase the supply of university graduates, research systems in some of the wealthier less-developed countries appear to have difficulty recruiting or retaining qualified staff. In part, this is because salaries and work conditions in public agricultural research institutes are not competitive with other job opportunities. In a number of countries, for example, universities employ large numbers of PhDs in the agricultural sciences, while the national public agricultural research institutes employ few or none.

On the other hand, as argued earlier, a large proportion of PhDs on the research staff does not necessarily indicate a successful research program. The contemporary systems of Australia and New Zealand, for instance, have apparently achieved significant successes with a high proportion of staff at the BSc or MSc level, as did the US system in earlier years. While not discounting the value of training researchers to the PhD level, this would suggest that greater attention should be given to the research orientation and training within BSc and, especially, MSc programs at local universities rather than simply seeking a high proportion of PhDs through training abroad, particularly when such training is of questionable relevance.

## Size, Scope, and Spillovers

Since 1961-65, the average size of NARS has more than doubled, from around 400 to 880 researchers, as has average expenditure per system. In less-developed countries the average size of NARS has increased from 150 to 600 full-time-equivalent researchers. Nevertheless, 95 of the 130 NARS in less-developed countries still employ fewer than 200 researchers, while 39 systems employ fewer than 25 researchers. Only 14 employ more than 1000, illustrating that the growth and development of NARS in the past two decades has diverged significantly.

When analyzing the cost structures and effectiveness of a NARS, one needs to consider both the overall size and diversity of its operations and the agricultural system it serves.

The evidence on whether or not research operations are subject to economies of size is limited and far from definitive. In the case of a NARS, considerations of economies of size are confounded by the fact that these systems generate a wide diversity of products and services that vary in their commodity, technology, and agroecological specificity. For example, certain activities can relate to improving crops or to developing new breeds of plants suitable for specific agroecological zones within a country. Alternatively, research can be devoted to developing improved crop and soil management practices that will allow farmers across a range of agroecological zones to increase yields or improve pest and disease control.

Even in the absence of scale economies with regard to any particular line of research (e.g., a particular commodity research program), a system may well be able to generate economies of scope through a judicious choice in its portfolio of research activities. Such scope economies arise when a system can undertake a whole range of research endeavors more cheaply than if these endeavors were undertaken by separate research entities. These economies can be achieved, for example, by sharing staff, equipment, information, or know-how between different lines of research.

An important implication is that when a system can create sufficiently strong economies of scope, these can in turn lead to economies of scale across the whole range of its activities, even if such economies of scale do not arise for some individual research programs.

Of course diseconomies of scope can also arise, particularly among small systems that spread their limited resources across numerous research areas. Thus, small NARS will be unable to conduct research in all areas that may warrant attention in the agricultural systems they serve. They will have to make choices between areas of study, and this in turn requires some specialization and flexibility in response to opportunities as circumstances change.

The efficiency of a research system can also be increased by adapting research conducted elsewhere to local circumstances. The ability to capture research spillovers is particularly important for small NARS without the capacity to conduct much basic research themselves. The best source of spillover would seem to be neighboring countries with similar agricultural systems and agroecological features. This strategy would require a policy of hiring staff for their ability to adapt research to local situations rather than to carrying out original research. It also requires flexibility in the research system to identify and act upon opportunities arising from developments elsewhere.

## Financing Public Agricultural Research

A fundamental task facing NARS is to win public support for research and translate it to financial support. This must be done in the context of a public sector subject to competing claims on its scarce resources from various interest groups in society, be they producers, consumers, or taxpayers.

From this perspective, governments give differential preference to various programs, both within and between sectors of the economy, in response to such pressures. Thus, agricultural expenditures are committed to such programs as rural infrastructure, education, and credit, as well as to the generation and dissemination of new agricultural technologies. In addition, many poor countries implement distortionary pricing and marketing policies in the (short-run) pursuit of cheap food policies and the like, that ultimately tax agriculture and accelerate the transfer of resources from the sector. These same policies, in part by undervaluing the sector-specific assets in agriculture (e.g., land, irrigation facilities, etc.), can also lead to an underinvestment in agricultural research and the level of effort invested by farmers in searching for, evaluating, and adapting new agricultural technologies and practices.

To gain a full understanding of the observed disparities in the nature and level of support for agricultural research (and the ultimate productivity effects that flow therefrom) would require detailed consideration of these "political economy" forces — an exercise that would take us well beyond our brief. Rather, the aim here is to present some comparative evidence on the level of support for public agricultural research and place publicly funded research in the context of the overall level of support for agriculture.

A traditional measure of the level of support for agricultural research is the agricultural research-intensity ratio that expresses levels of research spending as a percentage of agricultural gross domestic product (AgGDP). Although a majority of the less-developed countries spent well above 0.5% of AgGDP on agricultural research in 1981-85, the weighted average was only 0.4% (table 4). This apparent difference between simple and weighted average is caused by the fact that the smaller less-developed countries tend to have substantially higher agricultural research-intensity ratios than the larger less-developed countries. The weighted average of the more-devel-

**Table 4. Agricultural Research-Intensity Ratios by Region and Income Group — Weighted Average**

| Region/income group[a] | 1961-65 | 1971-75 | 1981-85 |
|---|---|---|---|
| | % | % | % |
| Sub-Saharan Africa (37)[b] | 0.26 | 0.42 | 0.49 |
| China (1) | 0.41 | 0.39 | 0.39 |
| Asia & Pacific (15) | 0.14 | 0.22 | 0.32 |
| Latin America & Caribbean (26) | 0.30 | 0.46 | 0.58 |
| West Asia & North Africa (13) | 0.28 | 0.50 | 0.52 |
| Less-Developed Countries (92) | 0.24 | 0.34 | 0.41 |
| More-Developed Countries (18) | 0.96 | 1.41 | 2.03 |
| Low (30) | 0.22 | 0.27 | 0.35 |
| Lower-middle (28) | 0.24 | 0.35 | 0.40 |
| Middle (18) | 0.25 | 0.46 | 0.57 |
| Upper-middle (18) | 0.27 | 0.44 | 0.55 |
| High (16) | 1.08 | 1.57 | 2.23 |
| Total Sample (110) | 0.48 | 0.65 | 0.76 |

a. Countries assigned to income classes based on 1971-75 per capita GDP averages where low is <$600; lower-middle is $600-$1500; middle is $1500-3000; upper-middle is $3000-6000; and high is >$6000.
b. Bracketed figures represent number of countries in each region or income class.

oped countries was just on 2% in 1981-85. The southern European countries lagged significantly behind the other more-developed countries. When calculated by income group, a (not so surprising) strong correlation appears between per capita income and the agricultural research-intensity ratio.

Although agricultural research-intensity ratios approximately doubled in both more- and less-developed countries between 1961-65 and 1981-85, they declined in the latter half of that period in 37% of the less-developed countries, half of which were in sub-Saharan Africa.

Research investment has traditionally produced high levels of return compared with investments in other areas, up to and exceeding 35% in some instances. This fact, and the gap in investment with more-developed countries, has led some authorities to conclude that many less-developed countries underinvest in agricultural research. It has also led to calls from the World Bank, for example, to set a research investment target of 2% of AgGDP.

Research-intensity ratios are useful to policymakers because they indicate the importance other countries attach to agricultural research. But they may be an unreliable indicator of the appropriateness of a nation's research investment because the efficacy of a country's research endeavor differs between regions and over time. It could therefore be more helpful, instead of setting arbitrary targets for research investment, to fix a desired rate of return from the investment made — to set targets that would push rates of return to below 20%, for example.

The data presented in table 5 show that low-income countries spend a considerably greater share of overall public expenditures on agriculture and agricultural research than high-income countries, around 10% on agriculture and 0.6% on agricultural research, compared with 3% and 0.2%, respectively, in high-income countries. Moreover, the share of public expenditures on agriculture directed specifically to research remains surprisingly constant, at around 8% in 1981-85, for poor and rich countries alike. This contrasts markedly with the data in table 4 that report agricultural research-intensity ratios for poor countries that are substantially lower than those for rich countries.

To understand why this is so would involve, at a minimum, a detailed consideration of the decision-making processes whereby public research

**Table 5. Agricultural and Agricultural Research Shares in Public-Sector Expenditures**

| Income group[a] | 1971-75 | 1976-80 | 1981-85 |
|---|---|---|---|
| | *Percentage of agricultural expenditures in total government expenditures* | | |
| Low (13)[b] | 10.5 | 11.7 | 11.2 |
| Lower-middle (18) | 7.5 | 8.1 | 9.3 |
| Middle (12) | 6.5 | 5.7 | 5.2 |
| Upper-middle (12) | 6.7 | 4.7 | 4.3 |
| High (15) | 3.0 | 2.7 | 2.5 |
| Total sample (70) | 7.1 | 6.9 | 6.8 |
| | *Percentage of agricultural research expenditures in total government expenditures* | | |
| Low (13) | 0.8 | 0.7 | 0.7 |
| Lower-middle (18) | 0.7 | 0.5 | 0.6 |
| Middle (12) | 0.5 | 0.4 | 0.4 |
| Upper-middle (12) | 0.2 | 0.2 | 0.2 |
| High (15) | 0.3 | 0.2 | 0.2 |
| Total sample (70) | 0.5 | 0.4 | 0.4 |

*Note*: All data represent simple averages across all countries in each income class.

a. Countries assigned to income classes based on 1971-75 per capita GDP averages where low is <$600; lower-middle is $600-1500; middle is $1500-3000; upper-middle is $3000-6000; and high is > $6000.

b. Bracketed figures represent number of countries in each income class.

investments, pricing policies, and the like are jointly determined. Particular attention would need to be given to the relative incidence of research benefits and costs (across producers, consumers, and taxpayers) in relation to alternative policy instruments, be they investing in rural public goods, such as agricultural research versus taxes, subsidies, production quotas, and the like.

But, some macro-level data suggest what political economy forces are at work here. While total government spending on agriculture, indexed over the agricultural population, increased dramatically by a factor of 85 times, from around $21 per capita in the low-income countries to $1800 per capita in the high-income countries, there is only a corresponding eightfold increase in agricultural spending indexed over the total population. Per capita spending on agricultural research follows a similar pattern. Thus, as one moves from low- to high-income countries, the level of per capita "benefits" or transfers accruing to rural-based coalitions may well increase at a disproportionately larger rate than the per capita incidence of "costs" associated with such programs. If this were the case, then the willingness of rural-based coalitions to lobby governments in support of agricultural research (and other forms of interventions that transfer resources to agriculture rather than the nonagricultural sector) may in turn be positively associated with per capita income.

Over the past few decades, for many but not all NARS, a goodly portion of public-sector research budgets have been financed from general taxpayer revenues. More recently, an increasing number of systems have begun to move (or at least contemplate moving) the burden of support away from the general taxpayer and closer to those (be they farmers, large commercial estate-crop operations, or private input and processing companies) who are among the direct beneficiaries of research. These tendencies are not only a response to greater budgetary pressures arising from tighter fiscal policies but are also viewed as a means to achieve a more complete and seemingly equitable correspondence between the incidence of research benefits and the sources of support for publicly executed research.

For those services provided directly by research agencies within the public sector, there still remains a policy concern over how these activities are to be financed. In addition to funding agricultural research out of general revenues (involving taxpayers to both domestic and donor governments), there are many cost-recovery mechanisms that may be (and indeed, are being) used. Alternative sources of revenue for public research systems include taxes or legislatively sanctioned check-off schemes on agricultural output or exports, fee-for-service (i.e., contract) research, license fees related to third-party use of publicly provided research output — or even the proceeds from state-run football pools, as in the case of the Norwegian system!

## Closing Comments

While the past contributions of agricultural research to productivity gains and the improvements in living standards that followed have been impressive, the challenges that lay ahead are considerable indeed. There will be unprecedented increases in the demand for additional food and fiber production, while the threats to even achieving, let alone sustaining, such levels of output in the face of a degrading natural resource base for agriculture loom large. Such threats appear as real for the more-favored, intensively cultivated production environments as they are for the more marginal areas.

There are unlikely to be any quick technological fixes to addressing these concerns. In fact, for the more immediate term, at least, maintaining as well as enhancing past productivity increases is likely to come from the incremental gains arising from a whole array of new technologies and management practices. While individually less "newsworthy" than the Green Revolution technologies of the past, these sources of growth, when taken as a group, will nevertheless be just as real.

But to realize these output gains in a manner that preserves the environment will require a sustained commitment to national and international research endeavors. While many countries experienced a substantial growth in their research capacity in the 1960s and 1970s, a considerable number saw an erosion of their public-sector research capacity in the 1980s. Although privately sponsored research endeavors are sure to grow in the future, the corollary is not necessarily to cut back on public-sector investments. In fact, the substantial growth in privately sponsored research in the US over the past several decades occurred in conjunction with a continued, albeit slower, growth in public-sector research investments.

To fully harness the potential complementarities and synergy between public and private research endeavors will require that more attention be given to each sector's comparative research advantage. In particular, the gains to researching improved agricultural management and production practices — those that will play a large role in realizing sustainable improvements in agricultural output — are generally difficult to appropriate and are likely to remain the domain of the public sector. So, too, are the more basic, pre-technology types of research that in turn lay the foundations for the privately sponsored applied and adaptive research programs of tomorrow. Failure to support and nurture today's research endeavors may well reap many unfortunate and undesired consequences in the not-too-distant future.

# Scientific Advances in Agricultural Technologies as Opportunities for NARS: A Technology Assessment Perspective

*Jock R. Anderson*
Principal Economist
Agriculture and Rural Development Department
The World Bank

## Costs of Technological Modifications

Given the economic rationality of the agricultural agents (mainly farmers) who make or break the business of technological change, profitability is a critical element in explaining what they do and motivating them generally. The cost side of the story is thus an important half of the problem. Particularly in considering modifications for resource-poor farmers, cost considerations may be an even bigger portion of the story because resource poverty in itself means that some technologies are effectively denied to literally billions of farmers. This will be especially the case if such items, particularly those of a capital nature, have a high foreign-exchange component.

Policies can moderate such negative effects but only in a very circumscribed way, given the resource poverty that so many governments also face. In fact, the trend in recent times has been for policy initiatives to reduce the role of governments in distorting the cost of imported items through the policy reform process of withdrawing such things as fertilizer subsidies. The World Bank, as one pro-active agency, has been forcefully instrumental in many of these recent changes. It has, unfortunately, been more successful in eliminating intervention on the cost-reducing input side than it has been in freeing up markets on the output side, so that in many cases farmers have been squeezed and economically disadvantaged in the sometimes slow process of economic and policy reform. Recent trends in many international commodity markets have also added to some of the difficulties in the past few years.

## Support Services

Many new technologies that, in principle, may be useful in assisting farmers to modernize their production and boost their productivity, require several different kinds of services that are often inadequately provided. In many countries, the hand of government has been heavy in the past provision of these services and, with the pressures to privatize and, indeed, the need to get the private sector effectively activated in this work, progress is often slower than would seem to be socially desirable. Development agencies, generally, and my own, in particular, need to articulate more effective means of aiding the development of the private sector in some of these areas of past neglect. There is nothing intrinsically difficult about selling products as mundane as fertilizer, and there is little rationale for any residual governmental role in such servicing. These same arguments apply to virtually all the inputs used by farmers, ranging from credit through to telecommunications.

## Difficulties in Technological Transfer

Several impediments limit the transferability of agricultural innovations. The general phenomenon we are up against here can be described as locational specificity, and it takes many forms because different inputs and agricultural processes are concerned. The problem is a universal one, and to mention just one concrete example from an industrial country, there is remarkably little transfer between maize hybrids from one county, let alone from one state to another, in the Corn Belt of the USA. Contrast, then, the difficulties of producing productive germplasm that can be widely adopted across highly disparate agroecological regions in parts of Africa, for instance.

## Social Impact of New Technologies

Determining the social dimension of the adoption of changed technologies is seldom easy, especially ex ante, but even ex post. The many careful studies that have now been made of this dimension in retrospective work, such as those in India relating to the Green Revolution and its distributional consequences, show us that there is an important temporal aspect to the processes. While the relatively economically advantaged farmers tend to profit earliest and gain most in absolute terms, it has been observed that, in a relatively short time, the less-advantaged farmers, and even landless laborers, through their boosted employment prospects, all share in the first-round gains from technological change. The local linkages and multipliers soon translate these first-round gains into quite broadly shared benefits from the basic productivity-enhancing effects emerging from agricultural innovation.

This somewhat sanguine view of the effectiveness of linkages should not be interpreted as implying that agricultural innovation is the salvation of the rural poor, in general, and of specially disadvantaged groups such as women farmers, for example. It is fundamentally difficult to invent and design technologies that can be used solely by such disadvantaged groups.

It is pleasing to note that the situation is not totally grim, however. There are fascinating examples of innovative programs directed to the particular resource needs of female-headed farm households in southern Malawi, for instance, that seem to be working quite well. These innovations have several dimensions, including a careful eye to the need to economize on scarce cash resources and to focus attention on innovations that can have immediate positive impacts on such groups as children — who have traditionally and increasingly suffered serious nutritional deprivation during the low-food-availability phases of the year. Such innovations as introducing "promiscuous" soybeans into multiple-cropping systems, and using appropriate but still low-cost methods of preparing these novel elements of the subsistence system mean that the energy metabolism of infants can be greatly improved at low cost and yet with considerable enhancement of the nutritional status of these growing numbers of extremely disadvantaged children.

There is, needless to say, much more to be done in this area, and development agencies need to be alert to picking up on the possibilities and pushing them with more than customary vigor. The international elements of the agricultural research system also need to be and, of course, are, similarly engaged in the search for appropriate low-cost innovations that can have such important social impacts.

## Economies of Size and Scope in Technology Generation

The field of technology generation has not been the subject of very much careful analytical study with regard to the economic efficiency of different sizes and shapes of institutional organizations. It is clear from both casual empiricism and simple reflection that, indeed, there are considerable economies of both size and scope in this business. With the need for particular disciplinary skills to forge progress on specialized aspects of research, it thus often requires a minimum of one fairly specialized person per research team to adequately cover the opportunities for scientific innovation.

It is probably the case that such economies of size are rapidly exhausted with movements to even quite modestly sized research organizations; but the consequences of this for very small research systems in countries that are probably too small to be economically viable in their own right means that such nations need to pursue imaginative approaches to institutionalizing their limited research capacity. The most obvious solution is to share the minimal research infrastructural investment with their neighbors or near neighbors who face kindred problems. In such ways the economies of size may be effectively exploited even in extremely small systems.

Similar remarks apply to issues of economies of scope. It is a sad fact of life but one that certainly adds to the interest and challenge of our deliberations that many very small countries, in fact, have such diverse resource situations and commodity mixes, and there is an inherent difficulty in trying to meet the needed commodity coverage with extremely thin resources. Again, such situations should encourage both the sorts of sharing mechanisms noted above and also policies of such small nations trying to come up with institutional means of borrowing or variously "stealing" innovative findings and practices. Development agencies concerned about these matters also need to improve their understanding of how such optimal technology-sharing arrangements may be fostered and developed.

These few remarks should be substantiated by more analytical studies of the particularities of different parts of the world, and such work is urgently required. It is hoped that studies will soon be to hand through the "small-countries" initiative of ISNAR.

## Sustainability

Sustainability as a useful word in our vocabulary may well have had its day. I am looking forward to being educated as to how other European languages are grappling with this word. In English the word has come to have so many meanings, each of them so vague in their span and implications that it no longer seems particularly useful in concrete discussion of agricultural technology. If, however, we take the term to imply a concern for the possible consequences for the resource base of adjustments to agricultural technique, then there is a happy meeting ground of most disciplinary perspectives. Concern about the implications for the resource base of any change in technique, whether it be related to soil fertility management, the maintenance of soil structure, or the minimization of soil erosion, to mention just a few, is certainly high on the agenda of most agronomists and other field workers. But the span of resource concerns really broadens into atmospheric resources and human resources, for instance.

Insightful scientific work in agriculture has always been concerned with sustainability questions, even though this may not have been addressed explicitly as such. The problem in empirical work is that many of the phenomena are intrinsically slow-paced, and thus there is considerable challenge for short-term investigations that are seeking to discover the long-term consequences of technological modifications. There is no ready answer to this dilemma except to note that improved techniques of measurement will mean that we are increasingly able to address these matters more definitively than we have been able to in recent decades; perhaps even too well, given that we can now at insignificant cost detect fractions of parts per billion of designated biocides.

What must be said in passing (although almost parenthetically) is that there are good reasons to posit questions about many elements of modern agricultural technologies. This is especially so in the domain of chemicals used for pest control, where concerns for human health should feature more significantly in the analysis of technological possibilities. As we move towards abandonment of chemicals with long lives and questionable health consequences towards those that have shorter-term impacts, there is increasing hope that, particularly when used in integrated pest-management programs, there will be less negative impact on human health and greater net positive impact on both agricultural production and the natural environment.

Again, many other agricultural practices are of environmental concern. The general heading of land degradation covers a multitude of sins, but one that is especially pressing in many irrigated areas is salinization. There is considerable scope for dealing with this problem in both a planning sense, through better-controlled irrigation, and in an ameliorating sense, through new investment in drainage, to deal with past problems. Some would also argue that another very human source of degradation is the reassignment of prime agricultural land to urban purposes. This is, indeed, a significant ongoing phenomenon that will add greatly to the challenge of the world feeding itself adequately.

## Institutional Sustainability

It is of paramount importance that the institutions servicing agriculture, particularly research institutions — which are necessarily long-term in their perspective — must be sustained and thus must also be sustainable. To the extent that these institutions are obliged to take shorter-term considerations because of donor constraints on project funding, for instance, there is a genuine worry about their "sustainability."

My own institution has not been innocent of these difficulties. Many past projects addressed to developing institutional capacity in less-developed countries had a highly time-bound life. Five years is simply too few for developing a sustainable institution, particularly when the continuation of funding is compromised by government fiscal problems at the end of the project period. I believe my own institution is about to change its temporal perception and to work much more consistently on rather longer-term projects when dealing, especially, with research, but also with extension projects.

It is thus easy to criticize the external donor community for their excessively myopic perspective on such matters, but we should not ignore the fact that national governments must also be encouraged to take longer-term perspectives themselves. This is really the root cause of the problems just noted. If national governments were willing and able to support such institutional capacity over a much longer period of time in an adequate operational manner, we would not have the difficulties that are proliferating around the less-developed world at the moment. This gets into matters of education at all levels, particularly of ministers of finance and their advisors, as to the time domains that must be addressed in such work.

## The Time Dimension

The only generalization that can be counted upon to be true is that the generation of new agricultural technologies surely takes time. Depending on the nature of the process being considered, the time may be short or long, and the range is great, even given some limits on the set of technologies considered. Plant breeding, as perhaps the most tried-and-true technological innovation, has a normal lead time of something like eight years for annual crops. Crop-management innovations can, however, be introduced on a much faster timescale, but here the difficulty is to evaluate them adequately through relevant field experience over a suitable range of seasons.

For irrigated agriculture, particularly in relatively dry environments, short periods of field testing may be adequate. This is not the case, unfortunately, in many rainfed areas with highly variable rainfall patterns and totals. Here there is no substitute for extensive multi-year testing to establish the worthiness of particular innovations. An additional challenge for the investigators is to seek to find innovations that are not only more profitable, on average, but are also helpful in reducing the risks faced by farm operators in their implementation.

In summary, while it is impossible to generalize about the time that will be needed for agricultural improvements to be developed and to have their desired effects, one point can nevertheless be made: because of the intrinsically slow processes involved, investors in agricultural research need to be patient if they are going to be wise and successful investors. Donor fatigue must be recognized for its political reality but compensated against through mechanisms designed to support the necessarily long-term gestations involved in nearly all facets of agricultural research. This will be all the more the case as NARS and IARCs move increasingly into "environmental" as opposed to "productivity-oriented" research.

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# Scientific Advances and Agricultural Technologies as Opportunities for NARS: The Case for Biotechnology

*G. J. Persley*
Biotechnology Manager
Agriculture and Rural Development Department
The World Bank

## Introduction

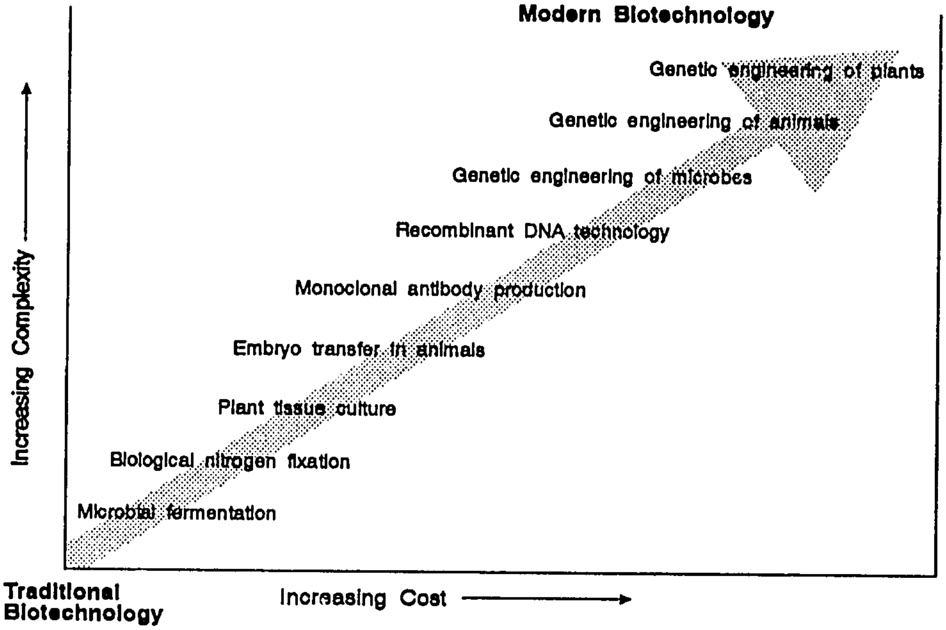
Biotechnology is not a new science. Indeed, it is not a science at all, but rather simply a *term*, coined to describe some new advances in the science of genetics over the past two decades. Genetics itself was first defined as a science by Gregor Mendel towards the end of the last century.

*Biotechnology* has been defined as "any technique that uses living organisms, or substances from those organisms, to make or modify a product, to improve plants or animals, or to develop microorganisms for specific uses" (OTA 1989).

*Biotechnology* comprises a continuum of technologies, ranging from long-established and widely used technologies, which are based on the commercial use of microbes and other living organisms, to the more strategic research on genetic engineering of plants and animals (figure 1).

*Biotechnology* includes "traditional biotechnology" covering well-established technologies used in commercially useful operations. These include the technologies presently used in brewing, biological control of pests, conventional animal vaccine production, and many others.

*Modern biotechnology* encompasses the use of more recently available technologies, particularly those based on the use of recombinant-DNA technology, monoclonal antibodies (MCA), and new cell- and tissue-culture techniques, including novel bioprocessing techniques.




Source: Jones (1990).

**Figure 1. Gradient of biotechnologies**

## Target Selection

The first step in assessing the usefulness of new technology to agriculture is to identify the problems that have proved intractable to conventional approaches and that may benefit from its application. In the analysis of what needs to be done, it is important to combine the skills of agricultural scientists and economists, who understand the commodity and its needs, with the skills of molecular biologists, who see new ways to approach an old problem.

The key to the successful application of biotechnology is to have a clear view as to what are

- the targets;
- the appropriate techniques;
- the desired products;
- the delivery systems required.

## Promising New Technologies

The first successful transfer of a plant gene from one species to another was made in 1983. In the nine years since, many different plant species have been genetically engineered. Useful resistance to selected pests and diseases have been located and introduced into crop plants. Approximately 400 field tests of potentially useful new crop varieties have been conducted in some 20 countries. A genetically modified bacterium has been released commercially to control a major disease of fruit trees. Products that double milk yield have been developed. New vaccines for animal diseases are in field trials. Yet, there is a perception abroad that the promises of modern biotechnology exceed the reality. Why is this so?

The perception is due partly to the excessive optimism of scientists, when they realized the power of the new techniques. It was also fuelled by the need to convince venture capitalists and other investors that biotechnology could deliver novel proprietary products in a shorter time than conventional agricultural research could. They also underestimated the linkages that would be required with conventional R&D in order to develop *products* for use in agriculture. This is especially so for crop production, where the linkages between new biotechnology and conventional plant breeding are critical.

Biotechnology as applied to agriculture is concerned with the following:

1. **agricultural microbiology**, to produce microorganisms beneficial to crop agriculture;

2. **cell and tissue culture**, including the rapid propagation of useful microorganisms and plant species;

3. **new diagnostics** based on the use of monoclonal antibodies and nucleic-acid probes, for the detection of pests and diseases, and the detection of foreign chemicals in food;

4. **genetic engineering** to introduce new traits into microbes, plants, and animals;

5. **new genetic mapping techniques** as an aid to conventional plant and animal breeding programs.

Some likely early applications of biotechnology to agriculture are illustrated below.

### *Cell and tissue culture*

Techniques for rapidly multiplying a wide range of plant species are becoming available. When combined with new diagnostic techniques, they can be used for the rapid propagation of improved, disease-free, high-value planting material. The techniques are proving especially useful for horticultural and vegetable crops (e.g., strawberries, potatoes, bananas) and for tree species for reforestation programs (e.g., eucalyptus).

### *Agricultural diagnostics*

New diagnostics based on the use of monoclonal antibodies and nucleic-acid probes are now available. They are being used for the detection and quantification of microorganisms and chemicals such as pesticides in food, and the identification of pathogens in plants and animals. Their practical applications include the development of disease-free planting material (e.g., banana, citrus, potato); quarantine, to increase the efficiency and reliability of quarantine services; and monitoring of disease development, to regulate pesticide use.

### *Genetic engineering*

The key components of genetic engineering are

1. identification and isolation of suitable genes to transfer;

2. delivery systems for introducing the desired gene into the recipient cells;

3. expression of the new genetic information in the recipient cells.

It is now theoretically possible to transfer a gene from any one organism to any other organism, including the transfer across former species barriers (e.g., a bacterial gene to a plant). Current research on crops is concentrating on the manipulation of single-gene characteristics such as resistance of plants to selected insects and viral diseases, improved protein quality, and longer shelf-life after harvest.

Especially rapid progress is being made in the development of new methods for tolerance to viral diseases. This technology seems particularly appropriate to tropical agriculture, where many viral diseases cause major yield losses in both annual and perennial crops.

Much effort is also going into introducing novel forms of insect tolerance. This is primarily based on the transfer of a toxin-producing gene from a soil-borne bacterium (*Bacillus thuringiensis* {Bt gene}) into plants. This technology will be specially useful in crops in which pesticide use is high, such as cotton and vegetables.

## Genetic Mapping

One technique of molecular biology that is becoming widely used in plant and animal breeding is the use of recombinant-DNA technology to produce a new type of genetic map (called an RFLP map). This technique is based on the use of genetic markers that are linked to specific traits. It is especially useful when selecting for complex characteristics, such as tolerance to drought or salinity.

Genetic maps are being developed for many of the major commodities as an additional tool for use in conventional plant-breeding programs (e.g., rice, maize, wheat). Genetic mapping is also becoming more widely used in animal breeding, to aid selection for specific traits (e.g., the bovine genome mapping project). The advantages of genetic mapping are that it increases the precision and reduces the time and cost of breeding programs. The technology requires sophisticated computer capability and knowledge of the genetics of a breeding population in order to be used efficiently and effectively in breeding programs.

## Time Frame

Although many promising new technologies are in the pipeline, there are few commercial applications of modern biotechnology in agriculture as yet. Given that genetic engineering of plants only became possible eight years ago, this is hardly surprising. It takes about 10 years to develop a new plant variety, biocontrol agent, or vaccine.

Initially it was thought that genetic engineering would significantly reduce the time for plant breeding. However, this is not always the case. A novel gene may only be able to be introduced into a variety that can be manipulated in culture, but which is of little agronomic value. This variety needs to be back-crossed into other more commercially useful varieties, or varieties suitable for other ecological zones. All this requires conventional plant breeding. In crop agriculture, a viable plant breeding program is an essential component for the successful use of modern biotechnology.

Several commodities have been assessed for their current constraints and the likely availability of new biotechnologies to aid in their solution. Substantial progress may be expected in the short term (up to five years) for potato, rapeseed, and rice; in the medium term (five to 10 years) for banana/plantain, cassava, and coffee; and in the long term (10+ years) for coconut, oilpalm, and wheat.

Most of these are "orphan commodities," ones in which there is little investment in modern biotechnology in industrialized countries, either because the commodity is not important in temperate areas or because no profits are likely for transnational companies. Yet, they are important food or export commodities in the Third World (e.g., cassava, banana/plantain). Special attention should be paid by international development agencies to these orphan commodities, to facilitate the application of biotechnology to the resolution of constraints in these important commodities.

## Socioeconomic Impact

Modern biotechnology is not expected to have any significant economic impact on agricultural production before the year 2000. After that, it will become an increasingly important component of new technologies for crop production.

Biotechnology is likely to change comparative advantages between countries and between commodities, particularly export commodities. The application of new technologies to export commodities will improve their competitive position in the international marketplace. The likely socioeconomic effects of biotechnology in the Third World are positive in terms of increasing the productivity of tropical commodities to meet food needs, offering new opportunities for the use of marginal lands, and reducing the use of agrochemicals.

There are also some potentially negative impacts, in that biotechnology offers the possibility of producing high-value products in tissue culture, thus displacing crops presently grown for export by the Third World (e.g., vanilla). The potential for negative substitution effects should be monitored and remedial strategies developed when economically damaging substitutional effects are identified.

## Private-Sector Investments

The major change in funding of agricultural research in industrialized countries in the past decade has been the greatly increased role of the private sector, largely in funding research in modern biotechnology. At least half of the current funding of R&D activities in agricultural biotechnology worldwide comes from the private sector.

The major reason for the greatly increased role of the private sector is that, for many of the new technologies, the process and/or the product is protectable. A company is thus able to appropriate many of the benefits of its research investments. Private companies are, therefore, much more likely to invest in modern biotechnology than in more conventional agricultural research. Private-sector investments are concentrated on markets in OECD countries. Increasingly, it is the major transnational agrochemical, food, and seed companies, rather than the small biotechnology companies, who are the major players in biotechnology in the private sector. In contrast, in developing countries, most support for biotechnology comes from the public sector, and neither local private-sector companies nor transnational companies are as yet substantially involved.

The situation suggests opportunities for creative partnerships between public- and private-sector interests, in both industrial and developing countries, to stimulate applications of new technologies to orphan commodities.

Greater public/private-sector collaboration in relation to biotechnology and its application to problems in the Third World will require

- continued public-sector investments, from both national and external sources;
- public/private-sector partnerships;
- innovative funding mechanisms on the part of international development agencies;
- involvement of both local private-sector companies and transnational companies.

## Intellectual Property Management

The major issue that will affect the application of biotechnology in agriculture is the management of intellectual property. The lack of patent protection is a major disincentive for private-sector investments in biotechnology in the Third World, by both local private-sector companies and transnational companies.

The advantage of the availability of intellectual property protection (by various mechanisms) is that it encourages the development of local research capability, as well as greater in-country investments in biotechnology. The major disadvantage is that it may involve giving proprietary protection to living organisms, which some consider to be part of the common heritage of mankind.

Each country needs to weigh the benefits and costs of intellectual property rights in biotechnology and frame its policies accordingly. Several mechanisms are being explored by countries that have decided to manage their own intellectual property.

## Biosafety

Another major issue that will affect the application of biotechnology to agriculture is the regulatory climate governing the release of new products. A safe and efficient regulatory environment is in itself a comparative advantage in biotechnology. Action has been taken in several countries to ensure environmental safety and public health in biotechnology applications in agriculture.

Over the past few years, risk-assessment procedures have been developed in several countries to assess instances of high, medium, and low levels of risk associated with the release of genetically engineered organisms. Guidelines have been developed in several countries to govern national regulatory systems.

National regulatory systems are based on a tiered system of responsibility, involving the following:

- a national review body;
- institutional biosafety committees;
- project biosafety reviews.

## Training

Training is required at several levels:

- bridging courses for research managers and mature scientists;
- postdoctoral fellowships;
- graduate training (MSc and PhD);
- undergraduate courses.

There is especially a need for bridging courses to introduce policymakers, research managers, and mature scientists to the new possibilities offered by modern biotechnology.

Postdoctoral fellowships in advanced laboratories are a key component in keeping young scientists in contact with the latest advances worldwide. Graduate and undergraduate training underpin the development of in-country capability in the basic biological sciences.

## National Strategies

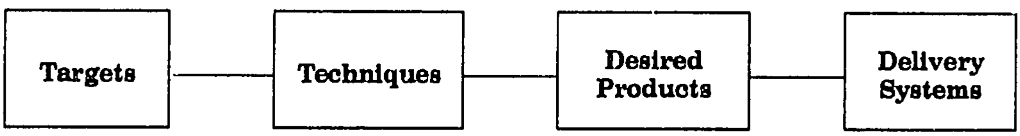
The development of a national strategy involving both the public and private sector is critical to making effective use of domestic and external resources. New initiatives are required, rather than new institutions. The aim should be to integrate new technologies into existing biological research programs.

The key elements in determining a national strategy are

1. target identification and priority determination;
2. financing from local and external sources;
3. access to technologies and information;
4. intellectual property management;
5. biosafety;
6. human resources.

## Conclusion

To reiterate, the successful application of modern biology to the problems of tropical agriculture will depend upon the clear definition of the following essential components, for *each* potential application:

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# Scientific Advances and Agricultural Technologies: The Problems and Perspectives of the New Approaches to Pest Management

*Thomas R. Odhiambo*
Director
The International Centre
of Insect Physiology and Ecology (ICIPE)

The year 1992 is a remarkably important celebratory as well as prayerful year in the global concern for the health and sustainability of the environment. It is the twentieth anniversary of the Stockholm Conference on the Environment, when the world community first decided to cobble together a coordinated program for addressing the environmental crisis emerging from both the uncaring industrial production by one part of the human community, and that being perpetuated by the uncared-for poverty of the other part of the world.

It is also the 30th anniversary of the publication of a singularly prophetic book, *Silent Spring*, written by Rachel Carson, which angered many scientists and industrialists by its sometimes extreme hyperbole, but which also galvanized ecologists and policymakers into a reassessment of the overwhelming role of chemical pesticides in the prevailing pest management theology. She lamented the fact that since the dawn of the Pesticide Age with the introduction of DDT and other synthetic, broad-spectrum, persistent insecticides soon after World War II for the eradication of agricultural insect pests and disease vectors, the advice of ecologists was not being taken about the impact of these new technologies and the existing alternatives that are more environment friendly. She concluded:

> The crusade to create a chemically sterile, insect-free world seems to have engendered a fanatic zeal on the part of many specialists and most of the so-called control agencies. On every hand there is evidence that those engaged in spraying operations exercise a ruthless power . . . . Future generations are unlikely to condone our lack of prudent concern for the integrity of the natural world that supports all life. (Carson 1962)

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It is in this context that — for those concerned with the half-century period of pest management dominated by chemical pesticides — the United Nations Conference on Environment and Development, to be held in Rio de Janeiro in June 1992, is not only a world forum for reassessing the gains that have been made since *Silent Spring* and the Stockholm Declaration on the Environment, but also a time to agree on at least three important general conclusions we have arrived at during this half-century-old Pesticide Age. First, that the pest management approach that insists on the eradication of insect pests and disease vectors is both unfeasible and anti-scientific. Second, that, as the Cornell University entomologist Thomas Eisner recently averred succinctly, "Bugs are not going to inherit the earth. They own it now. So we might as well make peace with the landlord" (Holdane 1989). And, third, that the Pesticide Age is definitely over. In its place, the Era of Integrated Pest Management (IPM), when pest control technologies will be information-intensive and will take the agroecosystem as its unit of operation within the context of biological diversity, is coming into its own since its early, tentative beginnings three decades ago.

Even so, there are skeptics, perhaps most clearly demonstrated by Oka (1987). He noted the progressive increase of rice production from 1950 to 1984 in Southeast Asia (for example, from his own Indonesia, an increase from 1.58 tons per hectare in 1950 to 2.13 tons/ha in 1984, or in Malaysia from 1.67 to 2.66 tons/ha in the same period), and he attributed it to the adoption of Green Revolution technologies, including the use of pesticides. Indeed, he asserted that the use of pesticides is increasing

> because pesticides have demonstrated their potential to increase yield and many people believe that other control alternatives, such as resistance [of crops to pests] or intensification of biological control, are slow and limited. (Oka 1987)

In contrast to Oka's assertion, Pimentel et al. (1989) have estimated that, in spite of very heavy pesticide applications in the United States of America since 1945, about 37% of total potential US crop production (or approximately US$ 50 billion) is lost to pests every year. Indeed, it appears that losses caused by insects have, surprisingly, increased nearly twofold (from 7% of crop yields in 1945 to about 13% in 1989), even though the application of insecticides has increased more than tenfold over the same period. Added to these yield losses due to pests, there are the direct losses due to the impact of the pesticides themselves — in terms of destruction of natural enemies, destruction of honeybees and other insect pollinators, and social and environmental losses, all estimated at US$ 1 billion a year (Pimental et al. 1989). Thus, DDT and its synthetic chemical insecticide successors have become part of the problem of more durable and sustainable pest management the world over.

We need to come to grips now with IPM, not simply as a new theology in pest management, however rational, but because it is feasible in its scientific goals, it is efficacious in its technological and economic implementation, and it is frugal in its ecological and environmental impact.

## The Era of IPM

The idea of IPM was first formally mooted in 1959 by Stern et al. (1959) when they wrote about the "integrated control concept." Soon after, at a symposium organized by FAO on integrated pest control in 1965, Smith and Reynolds (1965) put this concept on a more concrete basis, referring to it as "a system which uses all suitable methods in as compatible a manner as possible." This definition has been more recently updated and fine-tuned by the Office of Technology Assessment in the US, which considers IPM as, "The optimization of pest control measures in an economically and ecologically sound manner accomplished by the coordinated use of multiple tactics to assure stable crop production and to maintain pest damage below the economic injury level while minimizing hazards to humans, animals, plants and the environment" (Office of Technology Assessment 1990). Some of these tactics which seem to offer the most profound contribution to durable and sustainable IPM in the immediate future are intercropping (or polyculture), plant resistance to pests, microbial pesticides, pheromones, and biological control using insect predators and parasitoids.

It has become apparent over the last decade or so that the ancients often developed over the centuries (especially in the tropics) traditional cropping systems that have shown stability, resilience, and efficiency, and from which we have derived in modern times some of our most important cultivars and land-races (Thurston 1990). These cropping systems comprised a polycultural pattern of cultivation, some of whose elements included pest-tolerant cultivars or resistant crop varieties. The International Centre of Insect Physiology and Ecology (ICIPE) has focused considerable effort since the early 1980s on fathoming the basic factors responsible for the seeming success of these intercropping systems, in terms of stability of crop production and in terms of resilience in anti-pest status (ICIPE 1991).

These investigations have involved two types of polycultural cropping patterns: host-nonhost interspecific intercropping (e.g., sorghum-cowpea intercropping), and host-host intervarietal intercropping (e.g., the intercropping of two or more different cultivars of sorghum in the same field). The first cropping pattern has shown that in cultivating a host plant (such as sorghum) for stemborers (such as the spotted moth, *Chilo partellus*) in alternate rows with a nonhost plant (such as cowpea), this design may well result in the stem-borer population on the host plant being considerably suppressed. For instance, experiments in both field station conditions and in farmers' own plots have revealed that the severity of stemborer attack on a tolerant cultivar of sorghum (e.g., IS–18520) intercropped with cowpea (e.g., ICV–6) is less than half the level sustained by the same sorghum cultivar grown as a monocrop, or grown as an intercrop with another host plant species (e.g., maize Katumani Composite) (Omolo and Seshu Reddy 1985).

Similarly, the second cropping pattern has shown that the combined larval and pupal density of the stem-borer *C. partellus* on two sorghum cultivars intercropped together (e.g., IS–18520 and IS–4660) was low (0.40 and 0.38 per plant, respectively) in contrast to the significantly higher larval-cum-pupal densities in either cultivar singly cropped (i.e., 0.51 per plant) (Omolo, Olimo, and Simbi 1990). The regulatory factors underlying such pest behavior under more diversified microhabitats is still little understood and offers a tremendous challenge for those with an inclination to study the biophysical and semiochemical environments of such situations.

As a forerunner of the sort of exciting observations that may well emerge from such experimentation, Miller and Cowles (1990) have put forward a stimulodeterrent diversion (SDD) hypothesis, in which they have suggested how one strategy of behavior-modifying allelochemicals may be employed to successfully and persistently divert insect pests from their host plant. Under this hypothesis, an insect pest would be exposed to two allelochemicals having opposite behavior destinations as a means of protecting the host plant.

In one experimental set-up they exposed the onion maggot, *Delia antigua*, to the deterrent cinnamaldehyde (painted onto onion seedlings at the three-to-five-leaf stage), and at the same time provided an attractant diversionary trap crop, in the form of culled onion bulbs planted deeply into the soil, which attract gravid females for egg-laying. It was shown that the greatest reduction in oviposition occurred when both the seedlings (with deterrent allelochemicals) and culled onions (providing the oviposition attractant) were planted in the same field concurrently. There was drastic reduction of oviposition on the seedlings (69 eggs per seedling) under these circumstances, as compared to the intense oviposition with only the deterrent seedlings alone (127 eggs per seedling). The point is that, under high deterrence, gravid flies are stopped from egg-laying for a time, but eventually this resistance to oviposit is overcome and the flies lay the full complement of their eggs on any substrate, including the seedlings (Miller and Cowles 1990).

Plant-resistance strategies offer similarly exciting challenges, even though this is a traditional approach for pest suppression that has been employed from very early times. It became forgotten during the Pesticide Age, especially because of the early successes of Green Revolution strategies when the pesticide umbrella seemed to be destined to provide a lasting protective cover. The classification of the expression of crop resistance in terms of its genetic basis is important but not adequate, nor is the explanation of this phenomenon in terms of antibiosis and similar omnibus physiological conditions.

An interesting aspect of developments in this area is the artificial enhancement of resistance of crops through the implantation of the toxin genes of microbes pathogenic to target pests. Such transgenic plants would then produce their own protective proteins, the so-called insecticidal crystal proteins (ICPs), through plant transformation procedures. The potential problem is the emergence of field resistance of pests to the microbial gene conferring such crop resistance, for instance those imparted by the *Bacillus thuringiensis* endotoxin gene.

It is known already that one can undertake laboratory selection experiments which would lead to high levels of resistance of a number of pests (for example, the tobacco budworm, *Heliothis virescens*, and the Indian meal moth, *Plodia interpunctella*) to *B. thuringiensis* ICPs (Van Rie et al. 1990). There is some evidence that such resistance in, for example, *P. interpunctella*, is due to an alteration of the binding success between the particular ICP and the receptor sites located on the brush border membrane of the mid-gut epithelium (Van Rie et al. 1990).

Such potential problems with transgenic plants bearing ICP genes have made a number of entomologists rather skeptical of the long-term practical outcome of such a strategy (Van Emden 1991). Others have experimented with developing transgenic plants having genes for the enzymes chitinase and lysozyme (Schell and Mayer 1987). Chitinase dissolves chitin within the exoskeleton of insects, while lysozyme dissolves the cell walls of bacteria.

In all these cases of commercializing pest-resistance-enhanced transgenic plants, a vein of profound uneasiness runs, as expressed, for example, by van Emden (1991) recently:

> I do have very serious reservations about the use of transgenic techniques in developing insect resistant plants. By the very nature of the technique (including the need to use easy assayable markers), transgenic plant resistance is almost bound to involve allelochemicals governed by single genes. I understand that an armyworm (*Spodoptera*) has already, within three generations, shown tolerance to the *Bacillus thuringiensis* endotoxin transferred by biotechnology to tobacco plants.

Pheromones have not yet fulfilled the expectations that were fanned by the rapid advances made in the 1970s with the detailed identification of many pheromones. It was then optimistically thought that they would replace insecticides as the principal tactic for pest control, through the use of sex attractants (for moths, for instance) or aggregation pheromones (for bark beetles). This promise is unlikely to be fulfilled in its original form, although pheromones are likely to prove important in monitoring systems or in stimulo-deterrent diversionary strategies (Pickett 1991). As Sarode (1987) states pithily regarding pheromone use in India: "Conception of ideas is completed but delivery of action is awaited."

There is no doubt that the use of predators, parasitoids, and insect pathogens as biological control agents for insect pests is going to grow in the medium term, because of the juxtaposition of three key circumstances. First, it is a traditional practice with a long history of successes, starting from ancient China to the more recent times of classical biological control campaigns beginning with the introduction in 1889 of vedalia beetle (*Rodolia cardinalis*) from Australia into California to control cottony cushion scale (*Icerya purchasi*) then devastating the young citrus industry, which it did with resounding success. Indeed, classical biological control enjoyed unprecedented success as a pest control tactic until the coming of the Pesticide Age in the early 1950s, with the promise of providing a final solution to all insect pests and disease vectors.

Second, it is quite clear that the trial-and-error selection process for the introduction or augmentation of natural enemies should now be replaced by a more knowledge-intensive process of targeting the required natural enemies. This assumes much more detailed knowledge of the population dynamics and lifestyle of the relevant pest, its linkages to the phenology of the plants, and the interrelationship with all its natural enemies within the biophysical and biochemical environment of its diversified micro-habitat, including its polycultural base.

Under these circumstances, it seems that we should reexamine the potential of biological control through conservation; that is, by way of preventing any reduction in numbers or diversity of natural enemies of the target insect pest in its indigenous setting. Not much has been made of this strategy as yet, but a number of workers rate its future potential quite high, as observed by Mills (1990) two years ago:

> During the past century of classical biological control, the most successful projects have been those targeted against exotic pests that have not been of pest status in their region of origin. These projects have, by necessity, made use of a limited number of low-density natural enemies, those that are particularly effective in both locating and synchronizing with low-density host populations . . . . [But] it is likely that native pests and natural enemy augmentation or conservation will be the prime focus for biological control in the future. That is not to say that new pest invasions will cease . . . . In many regions, however, the most important pests are now either native or exotic species that have not been successfully controlled by natural-enemy importations.

## Prospects

It is evident that, up to now, IPM has only experienced slow adoption around the world. In the United States, for instance, only 8% of cropland is currently targeted for IPM (USAID 1990). This is not surprising, since we have become used to the idea that the only successful insect control technology is one which demonstrates rapid kill and eradication of the pest population.

We now need to accept a totally different pest management strategy: that of being comprehensively informed of the target insect pest and its biological, biochemical, and biophysical universe; that of acknowledging the variety of defence and avoidance mechanisms that the insect kind have evolved for surmounting a large number of aggressive accoutrements, whether naturally occurring or man-made, devised to defeat their herbivorous or carnivorous intentions; and that of aligning our long-term defenses that bring together, interactively and synergistically, a combination of management tactics that are multigenic and multicomponent, and utilize their own naturally occurring modifying biochemicals.

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# Scientific Advances and Agricultural Technologies as Opportunities for NARS: The Case of Forestry and Agroforestry

*R. Bruce Scott*
Deputy Director General
International Center for Research on Agro-Forestry (ICRAF)

During the 1980s agroforestry emerged as a major new approach to rural development and land-use management. The concept of agroforestry is simple. It is an approach to land use based on integrating trees and shrubs into crop and livestock production systems. Agroforestry has the potential to provide rural households with food, fodder, fuelwood, and other tree, crop, and animal products. At the same time agroforestry can help ensure the sustained productivity of the natural resource base by enhancing soil fertility, controlling erosion, and improving the microclimate of cropping and grazing lands.

This paper will briefly describe agroforestry technologies from the perspective of what they are and how they work by addressing the following: (1) Background to Agroforestry, (2) Developments in Agroforestry, and (3) Policy and Institutional Implications.

## Background to Agroforestry

In order to enhance the productivity and sustainability of their resource base, small-scale farmers and other land users in developing countries have for centuries practiced various forms of agroforestry, such as dispersed intercropping, the cultivation of home gardens, the multi-story cropping of perennials and annuals, boundary planting, and the use of trees and shrubs in erosion-control structures (Nair 1984). Although the practice of agroforestry is old, the science is new. The word *agroforestry* was first coined in the 1970s. Its rise as a science coincided with the realization that traditional land uses had much to teach professionals seeking to improve the productivity and sustainability of tropical agriculture, and at the same time, when various strands of professional experience converged to form a new consciousness of the multiple uses of land and the need to conserve, as well as exploit, natural resources.

As the science of agroforestry developed, a definition emerged:

> Agroforestry is a collective name for land-use systems and practices where woody perennials (trees, shrubs, bamboos, vines, etc.) are deliberately integrated with crops and/or animals on the same land management unit. The integration can be either in spacial mixture or in temporal sequence. There are normally both ecological and economic interactions between the woody and non-woody components to qualify as agroforestry. (Lundgren 1982)

The aim of the land user practicing agroforestry, or a scientist researching it, is to exploit the positive ecological and economic interactions between the woody and non-woody components in order to achieve higher productivity, sustainability, and/or diversity of output from the land than is possible through other forms of land use.

Fundamental to agroforestry is its potential to address combinations of problems through the same technology. Behind this potential lies the versatility of the woody perennial. The same species can serve both productive functions (such as fuelwood, fodder, and timber production) and service functions (such as soil fertility maintenance, erosion control, and microclimate enhancement). For this reason, multipurpose trees and shrubs (MPTS) are central to the concept of agroforestry.

MPTS are trees that make more than one major contribution to the land-use system. Indeed, this is a property of most trees. However, multipurpose trees are distinguished from species like pines or eucalyptus that are used primarily for wood production, often in large-scale timber plantations.

Most trees used in agroforestry grow quickly and may also fix atmospheric nitrogen in the soil (as do *Leucaena leucocephala* and *Sesbania sesban*), making this important nutrient available to other plants. However, some multipurpose trees have neither of these properties, such as fruit or timber trees that grow well in combination with annual crops.

Similarly, crops thrive under *Faidherbia albida*, a native of Africa's semi-arid regions. This tree's usefulness as an agroforestry species is related to its unusual production cycle. Unlike other trees, it produces leaves during the dry season and sheds them at the beginning of the rains, providing mulch for newly planted crops. During the normal growing season, the crops are in full sun because faidherbia's branches are bare. This odd cycle also makes the tree particularly useful for livestock production: the leaves provide nutritious fodder just when annual grasses are drying up.

There are many thousands of agroforestry systems, traditional and modern, but these can be classified into about 20 practices, or what we call *technol-*

*ogies*, as indicated in the following list (Young 1989).

1. Mainly Agrosilvicultural (trees with crops)
   Shifting cultivation
   Improved tree fallow
   Taungya
   Trees in cropland
   Multistory tree gardens
   Hedgerow intercropping (alley cropping)
   Boundary planting
   Trees and erosion-control structures
   Windbreaks and shelterbelts

2. Mainly Silvopastoral (trees with pastures and livestock)
   Trees on rangelands or pastures
   Plantation crop with pastures
   Live fences
   Fodder banks

3. Multipurpose Forestry (cf. also Taungya)
   Woodlots with multipurpose management
   Reclamation forestry leading to multiple use

4. Other Components Present
   Apiculture with forestry
   Aquaforestry (trees with fisheries)

Agroforestry technologies present many opportunities to achieve sustainable agricultural development for economic growth, but we must recognize that the challenge of developing appropriate land-use technologies must be accompanied by relevant policy and institutional changes to ensure success.

Historically, agricultural, forestry, and range management institutions have developed independently of each other — in education, research, extension, and legal matters. Furthermore, it was (and still is) rational that the mandates and aims of these sectoral institutions were to maximize production of individual crops and commodities from a given unit of land. Thus, commercially oriented monocropping and other single uses of land became, and still remain, the predominant forms of land use around which all institutions' work revolves.

What we have today are thus institutions and experts looking at individual components of farming systems, who can also do research and give advice on how to maximize production of these individual components but who lack the understanding and expertise to optimize all the various components to the advantage of the farmer.

An analogy with building construction can serve to highlight the problem. We have in land management the equivalent of masons, carpenters, electricians, and plumbers in the form of agronomists, foresters, livestock experts, and agricultural engineers, but we lack institutions performing the all-important roles of the architect and the civil engineer; i.e., an objective analysis of needs, an integrated design to satisfy the need, and the coordination to put it together (Lundgren and Young 1992).

The same disciplinary and sectoral constraints in dealing effectively with integrated environmental problems and potentials were highlighted by the World Commission on Environment and Development (the so-called "Brundtland Commission"):

> Sectoral organizations tend to pursue sectoral objectives and to treat their impacts on other sectors as side effects, taking them into account only if compelled to do so. Many of the environment and development problems that confront us have their roots in this sectoral fragmentation of responsibility. Sustainable development requires that such fragmentation be overcome. (WCED 1987)

## Developments in Agroforestry

It is one thing to look at problems and suggest solutions, but does agroforestry really work? Substantial evidence comes from traditional agroforestry systems that have been working well for a long time. These include, among others, the home gardens of Bangladesh and northern Tanzania, the multilayered coffee and cacao plantations of Central and South America, and the combination of trees and pastures in many semi-arid regions of the world.

Scientific evidence is also building up. Although agroforestry research is relatively new and has not yet produced the sheer volume of results associated with traditional areas of agriculture, claims about the potential of agroforestry are increasingly supported by experimental evidence.

Three hypotheses about agroforestry's potential relate to controlling soil erosion, soil fertility maintenance, and fodder. Some emerging results from agroforestry technologies dealing with these issues are examined below.

### *Controlling soil erosion*

In controlling soil erosion, trees may be added as a supplement to conventional soil-conservation structures and to help make productive use of the land they occupy. Trees can also control soil erosion on their own, by checking runoff and soil loss. Two agroforestry systems, in particular, provide this important function: contour-aligned hedgerow intercropping and multilayered tree gardens.

ICRAF has been testing and demonstrating the soil-conservation potential of agroforestry technologies at its field station in Machakos, Kenya, since 1984. In 1990, eight interlinked trials and demonstrations were in progress on land sloping at 14%, including trials focusing on the use of trees in hedgerows to control runoff and erosion, and demonstrations showing the supplementary use of trees as additions to conventional conservation structures.

At Machakos, hedgerow intercropping aligned on the contours has led to the formation of micro-terraces, with risers stabilized by tree roots and stems. This approach has created terraces as effectively as conventional construction techniques and has taken up a smaller proportion of land. Maize and cowpea yields have been maintained for seven years under contour-aligned hedgerow intercropping, and fruit trees planted in the ditches of conservation structures have also performed well. All indications are that a well-managed agroforestry system is as effective in controlling runoff and soil erosion as conventional approaches.

### *Maintaining soil fertility*

Soil-fertility maintenance is, without doubt, one of the most important functions of agroforestry. Trees in agroforestry systems contribute organic matter to the soil, recycle nutrients, and in some cases, fix atmospheric nitrogen.

Trees supply plant material on the soil surface in the form of litter and pruning and below the surface as fine roots that are shed continuously. Trees' root systems also help recycle plant nutrients that would otherwise be lost by leaching.

Under natural forest, less than 10% of the nutrients recycled between soils and plants are lost from the system. By contrast, under continuous cropping, nutrient losses can be 40% or more. Agroforestry systems can achieve a recycling ratio somewhere between these two values. The ratio can be improved if multipurpose trees are selected and managed to release nutrients into the soil just when the crop's nutrient requirements are greatest.

Evidence of agroforestry's capacity to enhance and maintain soil fertility comes from studies of plantation crop combinations in Central and South America. Coffee and cacao are grown under so-called "shade trees," which in fact fulfil many additional functions. The trees may be allowed to grow and are then cut for timber or pruned annually for fuelwood and mulch.

In experiments at Turrialba, Costa Rica, the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) showed that decomposing tree litter can return more nutrients to the soil than the level added through large application of fertilizer. Hedgerow-intercropping studies conducted by the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, also show substantial returns of nutrients to the soil from hedgerow pruning and root residues.

However, the systems most often cited as examples of successful hedgerow-intercropping agroforestry systems are found in areas dominated by base-rich naturally fertile soils, whereas the majority of soils in the humid and subhumid tropics are acid and infertile.

Biological results from various ICRAF experiments across Africa have given mixed crop responses (table 1).

**Table 1. Crop Yields (tons/ha)**

| Country | Hedgerow species | Crop | Control | Treatment |
|---|---|---|---|---|
| Cameroun (Yaounde) | *Calliandra* | Maize | 2.5 | 4.5 |
| Kenya (Maseno) | *Erythrina, Calliandra* | Maize | 2.3 | 3.5 |
| Burundi (Mashitsi) | *Calliandra* | Beans | 1.5 | 1.3 |
| Zambia (Chipata) | *Leucaena* | Maize | 2.5 | 2.4 |
| Zambia (Chalimbana) | *Sesbania* | Maize | 3.5 | 2.2 |

*Source:* ICRAF Program Review (unpublished).

Poor crop responses may be attributed to soil acidity, low rainfall, and insufficient biomass.

The economics of the technology is not only determined by its biological performance but also by the cost of introducing it. Important cost factors are establishment and maintenance (pruning) of the hedges.

Establishment costs are almost directly proportional to the number of trees established, and they range considerably, depending on method of establishment (seeds, bare-rooted seedlings, potted seedlings, cuttings) and price per unit of propagation material. Harvesting of hedges is another costly activity that needs to be timely to avoid shading of adjacent crops.

Another interesting agroforestry technology for improving soil fertility is improved fallow. ICRAF collaborates in improved fallow trials at Chalimbana Agricultural Research Station and Msekera Regional Research Station in Zambia. *Sesbania sesban*, a fast-growing leguminous tree, is planted at both sites in rotation with maize.

At Chalimbana, sesbania planted in January 1989 and cut to the ground the following December yielded 21 tons/ha (dry weight) of wood. Maize grain yields after the one-year sesbania fallow were double the yields from control plots and about 60% higher than yields from plots without the fallow but with fertilizer applied at the standard rate. Results at Msekera also indicated that a sesbania fallow could increase maize grain yields substantially in the crop immediately following the fallow and even in a second crop planted a year later.

In some cases, agroforestry may be able to replace chemical fertilizers. In others, the application of tree mulch can enhance the effects of fertilizer, allowing farmers to achieve the same results with lower fertilizer applications.

### *Making fodder available*

Shortage of animal feed, particularly in the dry season, is a problem farmers identify repeatedly. As we have seen, a number of agroforestry technologies attempt to address this issue. One such technology is grass and shrub bunds on sloping lands. This technology addresses two diagnosed problems: soil erosion and a shortage of protein for feeding animals, particularly dairy animals. Research conducted on this technology has shown that shrubs (managed as hedges) and grasses can be combined and interact positively with each other, in particular with calliandra and *Leucaena diversifolia* in the highland areas of Eastern Africa. *Sesbania sesban* proved to be difficult to manage because it dies after repeated pruning.

Research also showed that calliandra produced better during the dry season than *Leucaena diversifolia*. Grasses and shrubs can be established simultaneously; however, the productivity of the hedge is affected when established with already-established strips.

Research and field observations confirm that shrubs interact much better with adjacent crops than *Pennisetum purpureum*, a grass commonly grown on bunds in the highlands. Research plots in Rwerere, Rwanda, showed a yield decrease of up to 75% in crops adjacent to pennisetum (AFRENA 1990).

It is not surprising, therefore, that from an economic viewpoint, combinations of shrubs with less aggressive grasses such as *Setaria splendida* are a more cost-effective method of providing the required fodder than pennisetum alone or in combination with shrubs. A preliminary economic analysis indicated that at a daily milk yield of 4 kg, a saving in fodder cost of 60% may be thus obtained.

Research with this technology on sloping land has also shown that it is very effective in reducing soil erosion.

Grass strips on bunds, *Pennisetum purpureum* in particular, have been introduced in various parts of the land-use system, and hedges on bunds and boundaries for fodder, in combination with grasses, are therefore relatively easy to introduce.

No formal studies on the effect of the incorporation of the shrub leaves into the daily feed ration have been conducted yet. However, the positive effects have been well documented in the literature.

The main bottlenecks for the introduction of this labor-intensive method of fodder production is the market infrastructure for livestock products; in particular, dairy products. With a better market infrastructure, the chances for adoption of this technology will improve.

### *Costs and benefits of agroforestry interventions*

The resources required for agroforestry interventions are small in comparison with total resources used for agricultural activities on the farms. Annual labor requirements — even for intensive agroforestry activities — are calculated in days rather than weeks. The cash requirements for agroforestry are also minimal, mainly restricted to the costs of seedlings. The main problem for farmers is the amount of time it takes to realize a return on even the most minimal investment.

Directly linked to the benefits issue is the complexity of the technology and the skill requirements for managing the system.

Farmers understand the usefulness of trees and incorporate them in a variety of land-use practices. However, it is difficult for farmers to adopt agroforestry packages that require them to organize and supervise labor to perform new tasks in a fairly precise sequence or at precise time intervals. Simply acquiring, transporting, planting, and caring for seedlings may require more resources and more management skills than the average farmer can spare from subsistence activities.

Systems that require continuous protection, pruning, or weeding involve a high opportunity cost to the farm household and a greater risk of failure from unforeseen changes in the agricultural calendar.

### *Differential adoption of agroforestry by sex, age, and socioeconomic level*

While agroforestry intervention may be designed for a given ecological zone, it will be adopted to varying degrees by persons of different income levels, occupations, sex, age, and education. Access to land, labor, and capital further influence the degree to which an intervention will be adopted. For farm households with labor constraints, keeping to the prescribed pruning schedule may not be possible.

Richer farmers may be able to hire laborers for such tasks, but this approach involves greater risks, unless farm owners are able to provide close personal supervision of the labor force. Similarly, management-intensive activities, such as stall feeding of livestock in conjunction with the maintenance of fodder banks, may turn out to be appropriate only for a small group of wealthier and more entrepreneurial farmers. For poorer men and women, and for families with limited access to land, labor, or capital, modest agroforestry interventions are needed.

Closely linked to these policy and access questions are the issues of tree tenure, land tenure, and usufruct right. Ownership or secure use of land are frequently cited as preconditions for farmers to make long-term investments in agriculture. This argument appears particularly relevant for agroforestry, in which several years may elapse before the farmer can expect to receive a return on his or her investment. It is important to realize that the tenure issue has less to do with formal laws and regulation than with customary rights of various groups and individual members of these groups to make use of land and of different products growing on the land. Strategies of land management based on the usufruct rights of lineage members to land, or to particular resources on the land, are basic features of subsistence agriculture. Elders allocate lands for cultivation to adult males of the lineage, who in turn must allocate plots to all their wives. In this way land is retained as a corporate resource within the lineage. Land may be rented, but not purchased, by outsiders. It is important to realize that, contrary to popular opinion, the corporate management of lands and other productive resources in Africa is not diminishing in the face of modernization.

In contrast, trees are often individually owned, usually by the person who planted them, while land itself is annually redistributed. However, when land circulates within a limited pool of related people, agroforestry investments benefit the lineage as well as the individual planter. Thus, it has long been possible for smallholders to develop tree-crop plantations. Yet, since the management of tree crops and annual crops cannot be separated in a system, it would be more difficult for them to adopt alley farming.

There is no clear evidence that improved land tenure would provide a greater incentive for farmers to invest in agroforestry. Where agroforestry activities are demonstrably profitable, farmers appear to be willing to invest despite the insecurities of tenure, while farmers even with secure tenure will not adopt agroforestry practices that do not show positive returns on their investment in labor and capital. Secure returns are guaranteed, not by formal land tenure, but by the usufruct rights that link members of a group with a variety of productive resources, including both land and trees. Moves to promote individual land tenure may in fact tend to disenfranchise large segments of the local population by depriving them of their customary use rights.

### *Institutional issues*

Three important sets of institutional issues relate to agroforestry.

As we know, most research institutions have disciplinary mandates and find it difficult to integrate disciplines that deal with land-management issues. This is particularly true in the case of agroforestry. It is therefore important to devise mechanisms that facilitate cooperation between institutions dealing with agroforestry and not necessarily pursue the route of establishing separate agroforestry research institutions. In many countries, the emergence of national steering committees for agroforestry have developed national priorities and strategies for agroforestry by involving universities, national research institutions, extension agencies, and nongovernment organizations.

The second important institutional issue that has emerged relates to the absence of appropriate training and educational institutions with the experience to teach an integrated approach to the management of natural resources. As a consequence, trained professionals continue to examine, analyze, and prescribe solutions to problems from a monodisciplinary perspective. Special attention is required to develop teaching materials and modify educational curricula to train a new generation of professionals in land-use management.

Third, linkages between research and extension are weak. This is not unique to agroforestry. However, the field of agroforestry poses unique problems that traditional extension services cannot cope with. It is also evident that the most technical support to farmers for agroforestry is currently provided by NGOs and PVOs. Innovative and creative approaches to research and extension must be developed. Given the age-old practice of agroforestry, farmers must be directly involved in the design of research programs and technologies, and they must play a more active role in the validation, testing, and dissemination of technology. In short, extension workers must truly become facilitators — establishing the linkages between farmers and researchers.

This is not an exhaustive list of policy and institutional issues that require resolution to facilitate the adoption of agroforestry technologies. Issues such as the availability of inputs, prices of products, and value of public versus private goods are also important. From recent studies, however, it is clear that these issues have a direct bearing on the rates of adoption and must therefore be considered in the initial design of the technologies and the related research programs.

## Conclusion

Agroforestry should not be thought of as a panacea for solving land-use problems. There are certainly conditions, both environmental and socioeconomic, in which pure agriculture or forestry is a better form of land use. Nor should agroforestry be treated in isolation from other measures of land management. Good examples of how it can be combined with soil conservation, management of pests and diseases, and other methods of land-use improvement are the approaches known as "conservation farming" in Sri Lanka and "integrated land use" in Malawi.

No matter how and for what purposes we apply agroforestry, it must be realized that its full potential can only be achieved when our approach to research in land-use systems is problem oriented, interdisciplinary, beneficiary driven, and interinstitutional in scope. To achieve this, the focal point for setting the research agenda must always be the farmer and land user.

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# The Long-Term Vision of the CGIAR

*Alex F. McCalla*
Chair, Technical Advisory Committee
Consultative Group on International Agricultural Research
(CGIAR)

## Introduction

Over the past three years the Consultative Group on International Agricultural Research (CGIAR) has asked its Technical Advisory Committee (TAC) to undertake two major pieces of futuristic analysis. The first was to consider the possible addition of up to 10 institutes existing outside the CGIAR (the so-called nonassociated centers) to the CG family. The second was a major review of future priorities and strategies for the CGIAR. While logic would have suggested the opposite order, political reality dictated the actual sequencing. TAC, from the outset of the expansion analysis, insisted that the analysis be done against a background of emerging global trends and some conceptions of the possible form of the CGIAR in the medium and the long term. TAC enunciated those views in the expansion analysis (TAC Secretariat 1990). Now that the priority and strategy exercise is nearly complete (TAC/CGIAR 1991b), it is appropriate to revisit these longer-term visions of the CGIAR. What follows is drawn from these documents plus a further TAC paper prepared to expand the committee's views on ecoregional approaches to research (TAC/CGIAR 1991a).

Specifically, the paper proceeds in three steps. It first outlines what TAC saw as emerging long-term trends. Then the implications of these trends for the long-run structure of the CGIAR are presented. The paper closes by suggesting a medium-term vision that provides a possible transition from what currently exists toward the long-term vision.

## Long-Term Strategic Trends

The "long term" is defined not as a precise number of years, but more pragmatically in terms of the level of maturity of most national agricultural (including forestry and fisheries) research systems in developing countries. Thus, "long term" refers to the period when most of the national systems are strong enough to meet their national research needs — by their own efforts or in collaboration with others.

Therefore, the first long-term trend that would have a bearing on the role of the CGIAR is the gradual strengthening of the developing-country national systems. The rate of this strengthening will vary among countries and across continents. But if the CGIAR is to be judged a success, the capacity of national programs has to be increased. The CGIAR can be a participant in the strengthening process but cannot be the sole or major actor in the process.

Second, and parallel with the first, the number and capacity of regional mechanisms that foster and/or do agricultural research are likely to expand substantially in the long term. This is likely to be an outcome of increasing regional collaboration among developing countries and strong interests of donor agencies in building indigenous capacity in the developing world.

Third, as a result of stronger national programs and regional mechanisms and the trend towards increased collaboration, more research is likely to be conducted in a networking mode. This would parallel the present use of collaborative research networks in the developed countries. Advances in information technology could facilitate operating in a networking mode.

Fourth, there should be wider sharing of responsibilities for basic, strategic, applied, and adaptive research among developed and developing-country, transnational, and global institutions.

- Developing countries should be in a position to conduct adaptive research by themselves, with inputs as necessary from other institutions.

- Applied research responsibilities should be increasingly carried out by developing-country and transnational mechanisms.

- National institutions and transnational mechanisms will play an increasing role in strategic research. International institutions with global mandates would do mostly strategic research, in collaboration with regional mechanisms and national institutions in developing countries and basic research institutes around the globe.

- Basic research should not be viewed as only the province of developed-country institutions. Clearly, the development of strategic and basic research capacity in developing-countries' institutions *is absolutely indispensable to their necessary scientific maturity in the long term.*

Fifth, international institutions carrying out research at a global level should strengthen partnership relationships with developing countries and regional mechanisms. Those benefitting from such research should increasingly share in agenda setting, responsibility, decision-making power, and financing. Regional activities, as necessary, should be financed primarily by the countries that benefit from the work.

Sixth, in the developed countries, research responsibilities (particularly in the germplasm area) are already shifting from the public sector to the private sector. As more basic and applied research in these countries is carried out by private-sector institutions, there could be an increasing global need for international strategic research of particular relevance to developing countries.

Seventh, the research agendas of nations and regions will continue to be broadened to encompass expanded work on extension, agricultural development, and sustainability of natural resources. The research, training, and information activities of these institutions will cover the full spectrum from basic research to farmers' fields. Also, emphasis on production will be increasingly supplemented with work on environmental, institutional, and broader agricultural and resource-development concerns.

Although the scenario drawn above by necessity must be somewhat speculative, the trends noted reflect an extension of recent developments, colored by TAC's notions of what might be a realistic scenario.

## Possible Role of the CGIAR in the Long Term

Historically, the CGIAR has played primarily a "bridging," a "gap-filling," and a leadership role in agricultural research. It has served as a bridge between basic and strategic research institutions in advanced countries and national research institutions in developing countries. It has seen as one of its roles the filling of gaps in the continuum of basic-strategic-applied-adaptive research in order to keep that continuum intact at the developing-country, regional, and international levels. It has been a leader in internationalizing germplasm improvement, in the development of research methodologies, and in training developing-country scientists. The transition from this current role to the longer-term vision, which follows, is premised in several points.

First, in the long term the CGIAR must continue to be selective and deal with issues that are truly transnational and global. If the trends noted above are realized, the role of the CGIAR in the research spectrum should be of a different nature than it is at present because of the likely changes in the roles played by the other actors in the global scene. TAC's expectation is that the number of "gaps" should also diminish with the maturity of national and regional institutions. However, the analysis should be realistic and recognize that there will always be heterogeneity; i.e., not all national programs will be equally strong, even in the long run.

Stronger national and regional mechanisms would imply that over the long term the CGIAR should play a much smaller role in adaptive and applied research. This would leave strategic research as an area that can be contributed to by the CGIAR, in collaboration with regional and national institutions. In the long term, one principal responsibility of an institution like the CGIAR should be in the germplasm area.

Second, global strategic research related to the broadened research agenda mentioned in point seven in the previous section would require some international focal point, although the research itself could be carried out by many institutions in a collaborative fashion. This research would relate to solving problems of international significance in additional areas like natural-resource management, extension, research policy and management, and agricultural development.

Third, there may continue to be a need for an international focal point to provide wideranging information services to institutions and individuals worldwide.

Thus, in the long term, the CGIAR would be smaller and would function more as an international service institution than at present. Its research role would be limited essentially to strategic research on problems of global significance. It would be supported by all countries and institutions it serves, not only by advanced countries on a grant basis.

## Possible Long-Term Visions

If the long-term trends outlined have validity, then some characteristics of the CGIAR in, say, 2025, would be quite different from what they are now. The analysis is limited to international activities that address significant global, continental, or transnational problems, which exhibit substantial economies of scale, have potential for significant spillover, and are important for mature partnership relationships with national programs. The precise institutional form is difficult to predict.

### Germplasm

It is clear from the analysis that there will be, for the foreseeable future, an international need for activities in germplasm collection, characterization, conservation, and basic manipulation for plants and animals that have transnational and/or global utilization. Included here must be the preservation of biodiversity. The research related to these activities would likely be strategic and would involve applications of modern molecular biology as well as more traditional scientific techniques. These activities could include, as a minimum, the following:

1. annual plants of significance to meeting food needs and sustaining viable farming systems;

2. perennial plants — particularly trees — of importance to the continuum of land use;

3. animals of economic significance, including appropriate aquatic species.

The institutional form of long-term CGIAR support could take one of several shapes. Whatever the model, the activities would be highly focused and strategic, providing basic inputs into national programs around the world.

## Natural-Resource Management

Despite the fact that natural-resource management and its components — agronomy, natural forest management, soils, water, plant nutrition, agro-ecological characterization — are often categorized as being "location specific," there are and will remain strategic research issues and environmental problems that will transcend specific production systems and geographical and ecological regions. These include, for example, basic understanding of soil-water-plant relationships, energy balances, sustainable input-output models, transnational issues of water basins, migratory pests, and soil erosion. Perhaps these could be characterized as issues in the broad research area of the ecological foundations of sustainable production systems. Again, strategic research addressed to these issues should be international, should have economies of scale, and should have substantial spillover into national programs and regional mechanisms.

## Policy and Management

The current trends towards the internationalization of commerce, resource management, and science will continue and intensify in the foreseeable future. Global interdependence is a growing and permanent reality. Thus the number of major policy issues that are international — e.g., trade, capital investment, science — will become more complex. Further, as resource constraints — natural, financial, human — become more binding, issues of micro- and macro-management of research and human capital development resources will be transnational issues.

## Global Information

With the information explosion and the rapid development of multimedia communication techniques, the need for international mechanisms of collection, evaluation, and dissemination of research findings will increase. Improved mechanisms to facilitate international exchange of results, ideas, methods, and personnel will be critical.

This is not to suggest that the CGIAR would be the only or lead player in the international information scene. The CGIAR could be the lead mechanism in some, an active partner in others, only a financial contributor in still others, and an advocate in the remainder.

## A Possible Medium-Term Vision

On first reading, the long-term vision may seem at considerable variance with current calls for increased emphasis on broad issues of resource management on the multiple-land-use continuum, differentiated by agro-ecological regions. This apparent anomaly is addressed in this section by the presentation of a medium-term vision of internationally supported research that envisions the strengthening of ecoregional international efforts as part of the process of strengthening national programs and the development of transnational mechanisms of collaboration. As these occur, international research would increasingly focus on strictly global issues requiring strategic research.

In the medium term the CGIAR could have major activities of two types: global and ecoregional. Global activities would be focused on commodities and selected subject-matter areas, such as policy, resource management, conservation of germplasm, and the maintenance of biodiversity. Ecoregional activities would focus on applied and strategic research on the ecological foundations of sustainable production systems, commodity improvement in collaboration with global commodity activities, and interfaces with national partners.

### *Global activities*

- a series of global germplasm/plant improvement activities focused on selected commodities in the following groups: cereals, roots and tubers, legumes and pulses, vegetables, and multipurpose trees;
- a livestock activity addressing strategic and applied research issues in an integrated fashion on selected species of global significance;
- a fisheries and aquaculture activity on selected topics of international importance;
- a genetic resource activity focusing on conservation of genetic resources and the maintenance of biodiversity;
- a set of activities addressing strategic policy and management issues of global significance.

### *Ecoregional activities*

Evolving ecoregional activities would focus on coverage of major agroecological zones and ecosystems, but TAC does not see the necessity of complete coverage of all agroecological zones. Embedded in these ecoregional activities would be research on natural-resource management, sustainability, the land-use continuum (including crops, trees, and livestock), and commodity-based farming systems — all done in collaboration with national partners.

TAC deliberately did not specifically identify these activities as institutions, centers, or programs. They are presented as a possible description of the range of activities likely to be of transnational importance. Central to this, in the medium term, would be highly focused global germplasm and subject-matter activities collaborating with ecoregional activities and national programs.

## Concluding Comments

If it has been possible in the past to marry the requirements of a good commodity research program with the requirements of a program directed more broadly towards sustainable production systems, it is likely to become more difficult, if not impossible, in the future, for two main reasons.

First, research directed towards the improvement of sustainable production systems will have to be multicommodity in its coverage, and will have to move into areas of research on land use and conservation that lie outside those normally dealt with in commodity-production research. Second, research directed towards the improvement of commodities will increasingly become more specialized as researchers seek to exploit developments in biotechnology, giving rise to new economies of scale in the provision of the necessary laboratories and equipment.

Consequently, it is difficult to escape the conclusion that, in the medium-term future, there will be a need for at least two types of international institutional mechanisms: those with an ecoregional focus and those with a global focus — each dependent upon the other and collaborating closely to meet the needs of developing countries.

Close ties will be required between global and ecoregional mechanisms where research is needed on problems specific to the region. Regional scientists interacting with the national systems will play a major role in elucidating the needs of the farming systems and agricultural research institutions of the countries of the region. In the area of germplasm research, scientists working at the global level will be in continuous and close touch with this expertise. Ecoregional mechanisms would assume an even greater diversity of responsibilities than the original CGIAR centers that were given a regional responsibility in their mandate.

As these ecoregional mechanisms mature, they would increasingly be guided and would eventually be funded by the national programs of the ecoregion.

Thus, in the longer term the international agricultural system could focus primarily on global issues, as suggested in the long-term vision.

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# The Role of Research Networks and Regional Cooperative Programs in the Context of the 1990s

*Eduardo J. Trigo*
Director
Program II, Technology Generation and Transfer (IICA)

## Introduction

The advent of the 1990s has been accompanied by momentous changes. Politically, the end of the Cold War and the events in Eastern Europe are establishing a new framework for international relations and cooperation. Sweeping reforms, market deregulation, and the opening of economies are taking place throughout the world, and there is a growing trend toward economic integration and the consolidation of large trading blocs as the new organizational model for the world economy. A growing concern about the state of the environment and the natural-resource base is making sustainability issues a priority in the discussion of development strategies and options. Breakthroughs in microelectronics, informatics, and communications, new materials, sources of energy, and biotechnology are opening up a host of new scientific and technological opportunities.

In this context, agricultural research and technology development and transfer systems in the developing world are facing a transitional period in which they will need to restructure themselves, confront new demands, and adjust to new political, scientific, institutional, and economic environments. Research networks and horizontal scientific and technical cooperation programs have a particularly important role to play in this process, because they offer viable alternatives for increasing the effectiveness and efficiency of resource use, which can complement national technological development efforts.

In Latin America and the Caribbean (LAC), the above issues are of particular importance, not only because of the nature of the transformations that are taking place, but also because of the important roles that different types of horizontal research and technical cooperation structures have in the regional agricultural research and technology-transfer system. This paper briefly discusses some of the changes taking place and how they affect national research institutions and the role that regional organizations will have to play in the future.

The second section highlights some of the most important components of the LAC agricultural research systems, including existing networks and cooperative programs. The third section looks at some global and regional issues of importance for agricultural research and technology development and utilization. The fourth section focuses on the roles of regional organizations as they prepare to confront the emerging issues.

## The Latin American and Caribbean Agricultural Research and Technology-Transfer System

Public agricultural research and technology-transfer activities in LAC are organized around four main types of institutions: (1) the national agricultural research systems (NARS), (2) a number of research networks and cooperative programs, (3) two regional research and education centers (the Centro Agronómico Tropical de Investigación y Enseñanza [CATIE] and the Caribbean Agricultural Research and Development Institute [CARDI]), and (4) the three CGIAR institutes located in LAC (Centro Internacional de Mejoramiento del Maíz y Trigo [CIMMYT], Centro Internacional de Agricultura Tropical [CIAT], and Centro Internacional de la Papa [CIP]). These institutions are in constant interaction, and over the last 20 years they have evolved informal priority-setting and resource-allocation mechanisms, as well as the operational bases for information exchange and the design and implementation of collaborative and joint research activities.

This basic system is complemented by a variety of linkages with the other international centers of the CGIAR, as well as specialized research institutions and networks from the developed countries and other areas of the developing world. Over the past two decades there has also been significant development of private-sector research and technology-transfer activities, particularly as concerns seed and other input-related technologies. These initiatives, which at first were separate from and in some cases seen as competitive with public efforts, are now increasingly developing collaborative relations with the national institutions (Cirio 1991).

Public-sector research in LAC developed in the post-World War II period in the form of semiautonomous organizations initially oriented to adapting the technological knowledge available in the developed world to local conditions in the region. The risks associated with the lack of basic soil and climate information, as well as trained personnel and appropriate research facilities and budgetary resources, and the absence of other institutions willing to do and capable of doing the needed research, meant that only governments could undertake the responsibility. It was thought that this might best be done through concentrating efforts and resources in one institution with a national mandate.

Most public research programs expanded and diversified their activities rapidly during the 1960s and 1970s, and although research spending in real terms lagged behind the growth in infrastructure and number of scientists, the systems were able to achieve significant impact through production and productivity growth. It is important to emphasize that during this period their contribution was not only technology; they also played an important role in expanding information and human resources for agricultural activities — a key aspect of the development of the region's agricultural sector which is rarely taken into account as a product of the investments made in the NARS. It is fair to acknowledge, however, that the greatest impact was in relation to commercial crops and in technologies mostly suitable to the more enterprising medium- and large-scale farmers.

Regional cooperative activities go back to the 1950s, but it was only in the early 1970s that networks and cooperative programs initiated their rapid development and consolidation as one of the distinguishing features of the regional agricultural research system.

(The following discussion concentrates mainly on networks and regional cooperative programs, since they are the focus of this presentation. The regional activities of the IARCs are also of importance, however, and should be recognized. It should also be stressed that the international centers are also often key players in the networks and cooperative programs — particularly, but not only, those working with commodities as part of their mandates.)

Horizontal technical cooperation, either in the form of information exchange or improved coordination and development of joint research activities, is one of the most important elements in augmenting resources and increasing the effectiveness of national research and technology-transfer institutions. This is particularly so in the case of the smaller countries where there are economic limitations for the development of full-sized NARS able to attend to all research needs. Within Latin America and the Caribbean there exists considerable experience with this kind of mechanism which, over the last 15 years, has become a strategic complement to the functioning of most of the NARS in the region. Two particularly successful experiences often cited as models for this type of initiative are the Program for Cooperative Agricultural Research in the Southern Cone (PROCISUR) and the Program for Cooperative Agricultural Research in the Andean Subregion (PROCIANDINO).

Both PROCISUR and PROCIANDINO are flexible coordinating mechanisms for cooperative research and information exchange, in which each participating country retains its management responsibility and programming independence in accordance with its respective capability. Their structure includes a number of specific crop networks (PROCISUR: winter cereals, summer cereals, oil seeds, and cattle; PROCIANDINO: maize, potatoes, food legumes, and oil seeds) operating under an integrated secretariat provided by IICA. Overall priority setting, resource allocation, and supervision of activities are responsibilities of the directors of research of the participating countries, who meet at regular intervals, usually twice a year.

These programs have been in operation for over a decade now, and even though they were initially funded externally by the Inter-American Development Bank and IICA, they now have substantial direct financial support form the member countries themselves. Similar initiatives now exist for the basic grains (maize, beans, rice, and sorghum) in Central America and Panama, with donor support from the EEC, and there is a similar project proposal for the English-speaking Caribbean countries.

In addition, several other important regional programs have more specific foci. These include the Program for Regional Cooperation on Potatoes (PRECODEPA); the Research Network on Animal Production Systems in Latin America (RISPAL); the Regional Network for Cacao Technology Generation and Transfer (PROCACAO) in Central America and Panama; the Cooperative Program for the Protection and Modernization of Coffee Cultivation in Mexico, Central America, Panama, and the Dominican Republic (PROMECAFE); and the Caribbean Research Network on Rice.

All of these initiatives are important factors in resolving the problems and deficiencies in the national programs by promoting a more efficient use of available resources. For example, horizontal cooperation programs allow the relatively more capable national organizations to share resources and enhance their international influence and credibility. Likewise, these programs provide a mechanism for the smallest countries and organizations, which lack the necessary critical mass of human resources and financing to access valuable resources and support. Similar needs in the private sector are addressed by these cooperative efforts through research and technical assistance activities.

Although a quantitative evaluation of these efforts is difficult because of the natural lag time inherent in the enhancement of national research programs, some recent studies on PROCISUR show the investment returns for these types of activities to be extremely high. Evenson and da Cruz (1989) have found the internal rates of return for PROCISUR to be 191% for corn, 110% for wheat, and 179% for soybeans — levels that exceed most indexes of national investments in research at the commodity level, and even those estimated for the international agriculture research centers (IARCs). A more recent evaluation of PROCIANDINO, using a somewhat different methodology, found rates of return in excess of 23%, excluding all indirect effects (IARC activities and other NARS programs) (Rodríguez da Cruz and Díaz Avila 1991). From a qualitative perspective, it is important to emphasize that the cooperative programs and networks have also had an impact in strengthened relations between the international agricultural research centers and the beneficiary NARS. In fact, it can be said that some subregional networks are becoming effective substitutes for the centers' outreach programs. They are also making a significant contribution to the improvement of priority-setting mechanisms of the IARCs: by establishing the basis for a permanent and structured discussion and operational contact, they make it easier for the centers to reflect national needs and priorities in their program development processes.

Parallel to these initiatives, the region also has long experience with subregional research and development centers, particularly in Central America and the Caribbean, where CATIE, serving Central America, Panama, and Dominican Republic, and CARDI in the CARICOM countries, represent key elements of the agricultural research systems. CATIE's mandate is research and training in the areas of small-scale agriculture, agronomic sciences, and natural resources appropriate for Central America. The major programs are tropical crop improvement, crop production technologies, integrated natural resource management, and related postgraduate studies. CARDI focuses on agricultural research and development throughout the Caribbean in programs for livestock production, fruit and vegetable production, and technology transfer. CATIE and CARDI constitute the research nuclei for their subregions and are the technical foundation for long-term development strategies. Further, they serve to complement the activities of the international research centers while strengthening national research programs that are more oriented toward adaptive and applied research through direct extension services to farmers.

There is no doubt that horizontal cooperation programs have produced outstanding benefits for advanced developing countries as well as the smaller, less-developed ones. However, it must be stressed that, so far, they have been a complement to NARS activities, and their impact has been through their augmenting of national research capacities and the promotion of a more effective and efficient use of available resources.

## The Challenges Confronting Agricultural Research Institutions in Latin America and the Caribbean

As we move into the last decade of the century and look ahead to the next millennium, agricultural research institutions throughout the world confront a rapidly changing scientific, political, and economic environment. Their future success will depend on how well they are able to adapt to new conditions. While trends throughout the developing world are basically similar, some new issues are more global in nature, while others are restricted to particular political and economic processes in the region.

At the global level, the consolidation of microelectronics, informatics, new materials and sources of energy, and biotechnology as the cornerstones of a new technological paradigm, along with the emergence of sustainability in development, call for an in-depth review of research organization. The public nature of agricultural technology is rapidly changing, and proprietary protection in many technological fields is increasingly the rule. Sources and mechanisms for accessing relevant scientific knowledge in the new technologies are significantly different from those of the traditional agricultural sciences, and the costs and complexity of the needed research have greatly increased. Existing agricultural research structures, even in the most advanced developing countries, are not well adapted to handling the needed new linkages with the private sector and the advanced science centers outside the agricultural fields, not to mention the complexities of the multi- and interdisciplinary research required.

Structural adjustment and economic reform are rapidly changing the demands for new technologies and consequently the orientation of research and development activities. The deregulation of the economies and a new emphasis on trade liberalization brings the competitiveness of agricultural activities, and hence research and technological development, to the forefront of efforts to revitalize the region's economies. Research is needed for a new product mix (new crops) and a technological base (input intensities) that better reflect the comparative natural resource advantage of the region. This process will highlight the importance and priority of supporting research institutions, as well as point to new research priorities, both in terms of product and clientele. However, the structural adjustment and public-sector reform processes taking place in most countries are pointing in the opposite direction, stressing budgetary reductions and, in some cases, raising questions about the very legitimacy of public-sector involvement in these activities. How to bring together these two conflicting forces is a key aspect of the discussion on research organization and management in this part of the world.

Economic and political integration is another process with significant impact on the structure and functioning of NARS and regional research organizations. While previous efforts at economic integration were of a "protective" nature, the current process seeks to improve the region's ability to compete in international markets. An emphasis on competitiveness makes technological development particularly important.

Integration efforts will be successful to the degree that all the participants (countries or sectors within a country) can ably capitalize on their shared comparative advantages. This will be achieved only if every level is guaranteed equal access to key components of competitive technology. In "common-market" situations, only equal access to technology can transform the comparative advantages of the actors into real competitive advantages of the whole sector or country — whether through optimizing the use of common resources or by improving external competitiveness.

In the nonfarming sectors, the existence of better-developed markets for technological knowledge leads us to believe that the needed "equitable" access can be achieved through market mechanisms as the economies are deregulated, in the context of a common external tariff. In the agricultural sector, the public role of many technologies and the critical role the public institutions play in their development, make the existence of cooperative structures a necessary condition for successful economic integration.

These changes and trends will not only affect agricultural research at the national level; international and regional mechanisms will also see their roles changed in different ways, depending on what their institutional comparative advantages are. Let us look at some of the roles for regional organizations in the new world context.

## The Role of Research Networks and Regional Programs in the New World Context

The most important change that the 1990s will bring in the role of regional programs is that they will increasingly become more direct participants in the research and technology generation and transfer process in the region. Initially, the cooperative programs were developed to complement NARS and IARC activities, concentrating on facilitating information exchange and coordination functions. Recently, scientific and technological developments, and emerging research priorities, such as the environment and sustainability issues, as well as the prevailing economic and institutional scenarios, are showing that they must concentrate on more active joint planning, programming, and coordination roles. In some areas, such as information, they must become the institutional locus for the implementation of needed activities.

In assuming this role of "direct participants," regional programs will not, however, develop as entities separate from the NARS of the participating countries. They are operational mechanisms to increase resource-use efficiency through better coordination and research planning, as well as for the performance of certain functions that go beyond what individual NARS can undertake on their own. It is unlikely that they will develop research capabilities separate from those of the countries, but they will probably evolve toward more formalized structures for priority setting and joint program development among collaborating countries. They will also assume an increasingly important role in the development and operation of networks of "centers of excellence" with regional responsibilities and funding, particularly for high-investment, economy-of-scale research areas such as biotechnology, climatology, and environmental monitoring.

In the following sections, we briefly review some important aspects for the analysis and discussion of the role of regional programs in the rapidly changing context in which LAC agricultural research organizations must perform.

### *Strengthening NARS*

Research networks and cooperative programs formerly played an important role in strengthening NARS through the improvement of their research capabilities and increasing the impact of given levels of resources. Short-term human-resource development programs have been important complements of formal MS and PhD training, particularly in the smaller countries where the relatively small numbers of researchers made local training costly and inefficient. The increasing costs of training abroad, as well as the reduction of available funding from some of the traditional donors in this field, together with the lower priority accorded to training within the CGIAR, highlight the role that networks can play in this area. The Instituto Nacional de Tecnología Agropecuaria (INTA)-CIMMYT wheat training program in Argentina is a good example of the way in which the more-advanced NARS, the IARCs, and regional programs can collaborate to assure training opportunities for national researchers within a region. Personnel exchange programs can also play a significant role, particularly in areas such as information and research management, where training opportunities are limited, both in the countries and abroad.

Taking a more general perspective, networks and cooperative programs have contributed in a significant way to the institutional development of the participating NARS by facilitating the sharing of organizational and management experiences. These processes are particularly important at the present time, when many of the NARS in the LAC region are undergcing in-depth reviews as a consequence of public-sector reform programs. They will probably become even more important in the future, as the economic and political integration initiatives evolve and consolidate.

### *New priorities*

In the past, germplasm-related activities — usually in the basic food crops — and general information exchange constituted the bulk of the networks' and cooperative programs' activities. Recently, the growing importance of the new technologies — biotechnology, microelectronics, and informatics — as well as the need to harmonize the main technological policy orientations and instruments as part of economic integration processes, has resulted in a rapidly diversifying thematic coverage. The higher resource intensity, particularly in terms of human resources for biotechnology, along with a less location-specific character, especially for microelectronics and informatics, makes the new technologies attractive areas for regional cooperation. In the cases of PROCISUR and PROCIANDINO, these areas are already being considered as new priorities for joint action in both research and training.

In terms of institutional and policy issues, economic deregulation and integration focus on public-private-sector relationships, variety protection, intellectual property rights, and biosafety regulations. As some of the subregions in LAC (Andean, Southern Cone) approach the agreed dates for free movement of goods and services within the common-market areas, the existence of common definitions and approaches in these areas has become necessary for the efficient functioning of the new systems. Furthermore, in areas like biosafety, the prevailing tendencies are in the direction of the development of a single mechanism for all the member countries. The nature of the collaborative working relations, as well as the administrative and logistical support infrastructure already existing in the regional programs, makes them logical candidates to undertake responsibility in these areas — a process that has already begun.

Another area of increasing importance for network activities is export crops — particularly those with market agreements of different kinds. Coffee and cacao in Central America and banana in the Caribbean are good examples of this type of development.

## *The sustainability challenge*

Many of the sustainable production and environmental conservation issues are of a transnational character, and as such they will require a multinational approach. Regional cooperative programs appear to be particularly suited for work in biodiversity conservation and the management of common natural resources. The need for the development of a transnational approach is evident, because some of the largest biodiversity reserves are located in border areas, particularly in the Central and South American tropics. Also, the region's larger watersheds and river systems (Amazon, Orinoco, and Rio de la Plata) are multinational, and improved resource management can only be achieved if all involved countries adopt appropriate policies and technologies. There is a high probability that cooperative programs will evolve into structures covering not only research activities but also policy coordination (i.e., land use, water management, agrochemical regulations). The case of PROCITROPICOS is a good example of this tendency. The greater complexity of the multi- and interdisciplinary approaches needed to tackle natural resource management and sustainability issues, as well as the fact that many of the environmental impacts are of a transnational (in some cases even global) nature, are important reasons that suggest a growing role for regional programs in these fields.

### *Relationships with the IARCs*

Regional organizations have always maintained a close working relationship with the CGIAR centers, particularly in their mandated commodities, complementing their outreach programs and in some cases fully integrating their activities with those of the centers. In more recent times, their relationships have been moving to a more political level, both within the framework of the process of "devolution of responsibilities" initiated a few years ago, and also in relation to research priority setting at a regional level.

Cooperative programs, by bringing together a group of countries that share common resources and problems as well as politico-administrative systems, offer an efficient institutional setup for research policy dialogues and common priority analysis between the NARS and the IARCs. This feature will become increasingly important as regional differences reveal themselves within the developing world, and in the context of the new ecoregional centers currently promoted by the CGIAR. The ecoregional approach and the emphasis on land-use systems research bring to the fore the need for a more complex institutional relationship between the IARCs and their collaborating NARS. Agroforestry systems, improved soil management techniques, watershed management methodologies, and others involve not only technological dimensions but are also very sensitive to policy and institutional issues — aspects the IARCs are not well equipped to handle on their own.

These characteristics define a new complementarity between national and international institutions, with the IARCs developing "component" and methodological research in these new areas and the NARS providing the framework for the consideration of the more location-specific (and politically sensitive) policy, socioeconomic, and institutional aspects. The empirical fact that agroecological regions usually involve groups of countries strengthens even more the case for a closer relationship between the IARCs and regional programs. This closer relationship is already being developed in the case of CIAT through its active participation in the creation and implementation of the Cooperative Research Program for the South American Tropics (PROCITROPICOS), which covers the three main agroecosystems of tropical South America, and the recently established Consortium for Sustainable Development of the Central American Hillsides, through which CATIE, CIAT, and IICA have agreed to formally work together in the development of sustainable development strategies for that subregion.

### *The funding dilemma*

Networks and cooperative programs have until now relied heavily on external donor funding for their activities. The usual structure has been one in which special-project funding has provided for coordination costs and collaborative research operational budgets, while participating countries have covered personnel costs and some research expenses from their own regular budgets. In most cases, one donor would provide all the needed support, even in those situations where multiple commodities were included in the program.

In more recent times, and probably in response to the winding up of the original projects and the reluctance of donor agencies to continue to provide global support, there has been an increased move toward a more institutionalized and flexible structure with long-term core support for basic coordination activities being provided by organizations such as IICA, with the countries assuming a greater share of the funding for joint research activities. This is the case of the older programs in operation in LAC, such as PROCISUR and PROCIANDINO, as well as the export crop programs such as PROMECAFE. However, the resources available through these mechanisms are not sufficient to fully fund the increased amount of responsibilities they are expected to undertake in the future. To resolve this situation, most regional programs are being restructured on the basis of a minimum permanent mechanism for overall coordination and for implementing activities in common areas, such as information about germplasm conservation and assuring the administrative and logistical infrastructure through which donor support for specific areas is channelled when it becomes available.

This core-activity/special-project approach seems appropriate for those programs involving the larger countries in the region or for addressing political high-priority areas such as the humid tropics and the Amazon forest. However, it does not provide a real option for the programs linking the smaller countries, which are not able to assure the needed contributions to maintain the core structure. If the economic and political integration processes continue to evolve and consolidate, a number of other options, such as the creation of foundations and other types of trust funds, could be considered. In the Andean region, where a number of regional economic integration mechanisms exist, including a regional development promotion fund (the Corporación Andina de Fomento [CAF]), talks have been initiated to evaluate the feasibility of creating a trust fund for PROCIANDINO activities on the basis of donor as well as country contributions. Similar schemes, including the possibility of using loans from international development banks to support these types of programs, are being discussed for other situations. The problem to be resolved, however, is that there are no previous experiences with loans to groups of countries. Alternatives are now being analyzed in the context of the mechanisms that have been set up for financing specific economic integration processes.

## Some Final Comments

Over the last decade, networks and cooperative research programs have developed into an important complement for national and international research and technology-transfer activities, and in some cases, such as that of the LAC region, they have become a distinguishing feature of an emerging regional agricultural research system with a high-productivity potential. A brief analysis of the main challenges research institutions will have to confront in the 1990s and in the first decade of the new millennium shows that many of the anticipated demands and changes will make this type of mechanism more ubiquous and effective as complements of the NARS and IARCs in their efforts to create a new technological base needed for the development of a sustainable agriculture. In some cases, their role as facilitator or research coordinator will be upgraded to that of a direct participant. However, it must be emphasized that networks and cooperative programs are only complements of NARS and will never be a real option for national-level structures. Their development and consolidation does not replace the NARS research capacities. Consequently, how effectively they perform will ultimately depend on how strong they are. Unfortunately, in recent times ample evidence shows that NARS are not becoming stronger but, rather, weaker as structural adjustment and public-sector reform processes are placing undifferentiated restrictions on public-sector expenditures and operations.

The future of cooperative programs does not depend on whether they have a greater or smaller role to play, but on the future evolution of the global public research system. It will also depend on which strategies — particularly funding mechanisms — can be successfully designed to allow the cooperative programs to consolidate and effectively contribute to agricultural development.

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# Agricultural Research Institutions and the International Division of Labor: The View from Large National Agricultural Research Systems

*Adel El-Beltagy*
Director, Agricultural Research Center
Ministry of Agriculture and Land Reclamation, Egypt

As we look to the future, we need to continually balance demands on agricultural resources for food production with environmental concerns for soil and land (natural resources).

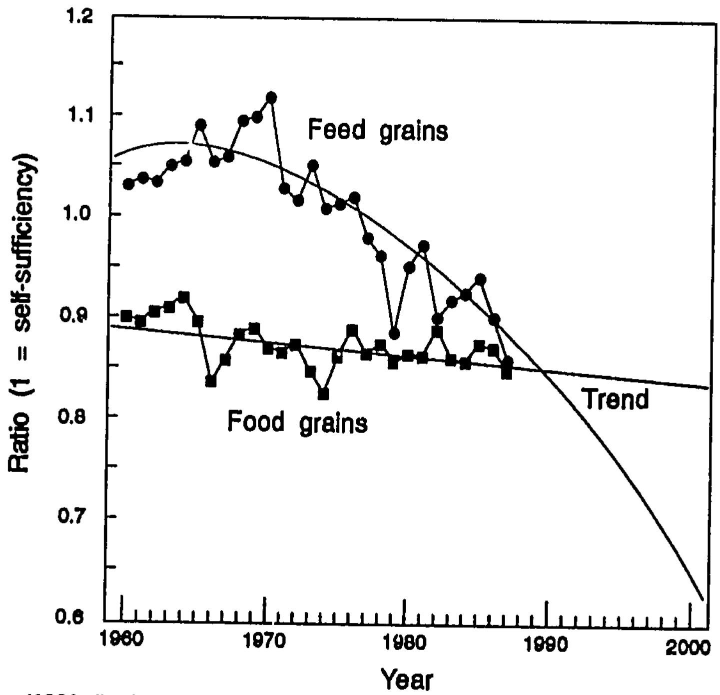
The challenge facing world agriculture today is to provide food, fiber, and industrial raw materials for an ever-growing world population, without affecting the future productivity of natural resources. Shortages in the food supply, coupled with demand for high production without appropriate management systems, could result in deterioration of the natural resource base. Meeting this challenge will require the continued support of science, research, and education. To meet environmental and food safety goals, it will require international coordination for food safety and environmental policy.

The new world order calls for an effort to look at the issue of agricultural sustainability in the context of the world, rather than on the national level. Sustainability is an issue that should be catered for not only by large national agricultural research systems (NARS) but also by the international agricultural research centers (IARCs) and international organizations.

An international code of ethics is highly needed for the preservation and maintenance of natural resources, not only on the national level, but the regional and international level as well. Moreover, large NARS could participate in land-use planning and development of agriculture development plans with emphasis on sustainability, providing experts in various disciplines to enhance the local capability for proper agro-management.

It is vital that international cooperation between NARS in the most industrial countries and the developing and underdeveloped countries must advance to a level that preserves a flow of information, exchange of knowledge, scientists, and international regional programs. The linkage and networking will necessitate a key role for the Consultative Group (CG) institutes to coordinate and foster these activities and ensure constructive interaction among NARS. Developing countries (as a group) have become less self-sufficient in feed grain since 1970. The downward trend is very rapid. Figure 1 shows the ratio of agricultural self-sufficiency for developing countries from 1961 to 1985. The production-consumption ratio for Australia, Canada, France, and the United States has been increasing during this time period. In contrast, the self-sufficiency ratio for a typical developing country, such as Algeria, has declined rapidly from 1961-1985. Fifty percent of the world population lives in countries with income levels of less than $400 per capita (figure 2). Only 15% of the world's population has an adequate per capita food supply (more than 1.7 tons of food).

The developing countries' share of world population, now 77%, is projected to rise to 80% by 2000 and 84% by 2025 (figure 3). This will impose stress on the consumption and production patterns of these countries. Enhancement of food production via agricultural research and technology transfer could minimize this gap.




*Source:* Vocke (1990, fig. 5).
*Note:* The ratio is calculated by dividing grain production by the sum of grain production and net grain imports.

**Figure 1.**
**Self-sufficiency ratios for grains in developing countries, 1961–1987**

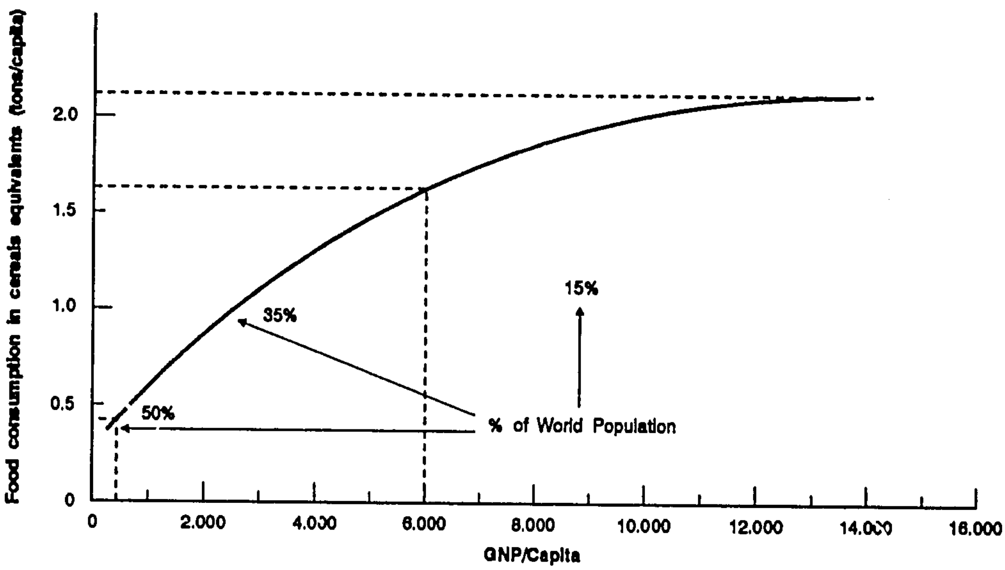



**Figure 2. Food consumption and income by world population**

Many observers believe that the Green Revolution has bypassed several developing countries. Africa, in particular, has missed the opportunity for agricultural development during the last three decades. Africa was the only region where per capita food production showed a downward trend during that period.

The World Food Council (WFC) adopted a new concept for the Green Revolution that was presented as an implementation plan for the Cairo Declaration in May 1989. The concept is known as the "Second Green Revolution" (SGR). The key ingredient of SGR is regional collaboration in research activities among NARS, in coordination with the IARCs and regional organizations in the same region to support an integrated regional agricultural development plan.

A number of conditions enhance the potential benefits of regional cooperation. Nations that are closer geographically and have strong relationships tend to be more successful in maintaining stronger collaboration. Moreover, potential benefits increase as the number of participating countries increases and the size of those countries increases.

Collaboration in research activities could have a number of positive impacts. Countries with severe shortages in scientific resources, such as sub-Saharan countries, could rely on other countries in the region with large NARS, such as Egypt, where an excess supply of skilled researchers exists. In addition, nations that are interdependent tend to become more politically allied, and the likelihood of political conflict is reduced.

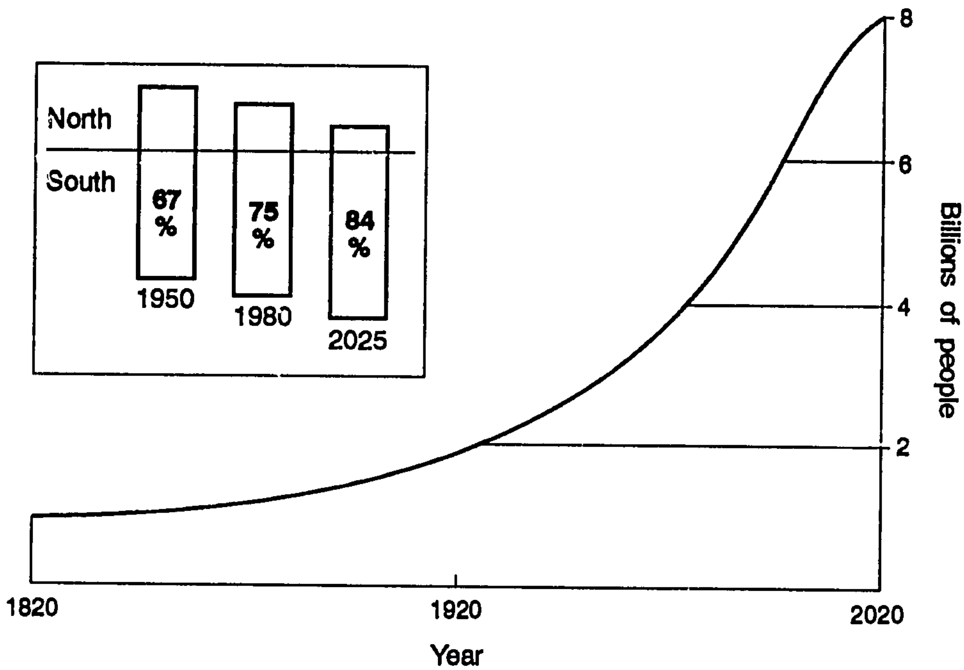



**Figure 3. World population trend and North-South distributions**

Complementarities in research activities, and similar climatic conditions and environments, would make it possible for research results to be readily transferable from one country to another. Therefore, each country could focus its effort on solving one problem and sharing the results with other countries.

Collaboration in research would lead to greater food production in the region and less variability in supply. Regional food security would be enhanced as a result. However, self-sufficiency is still difficult to attain because countries in the same region tend to grow the same crops. Increased production of the same crops might find its way to foreign markets. The question is, would it be possible for the countries in a given region to cooperate rather than to compete in the international market? The answer will depend on the nature of the traded commodity. Unlike the example of petroleum and OPEC, agricultural commodities are produced by millions of farmers and are difficult to store for long periods. The essence of successful cartels is the ability to maintain market shares and avoid competition. Every agricultural product has good alternatives, and raising the price (as a result of the cartel) will lead consumers to switch to other products. There was an attempt in the past to organize the major wheat-exporting countries in a cartel in order to control the international market. The attempt failed because of the above-mentioned reasons.

The development of close institutional links between NARS in the same region is essential to addressing the priority needs of the developing countries — as these countries see them, not as they are seen by developed countries. The Nile Valley Regional Project, for example, was established by Egypt, Sudan, and Ethiopia. Regarding human infrastructure, Egypt contributes 70 researchers and technicians. Sudan contributes 30 researchers and technicians, and Ethiopia contributes 20 researchers and technicians.

In addition, industrialized countries may become increasingly interested in concentrating and consolidating their efforts to support a group of NARS working within the scheme of the CG institutes for integrated agricultural regional development. The success of the CG institutes in Africa will depend on the impact of the political systems and the political will to implement it.

## Using Modern Technology in Crop Production

Experimental farming in Egypt began in 1898 at Giza under the authority of the Royal Agricultural Association. Research was established in 1903 in the chemistry, plant breeding, entomology, animal breeding, and seed-propagation departments. The veterinary pathology laboratory was established at Giza in 1904. Field experiments were conducted on four experiment stations established between 1900 and 1909.

After 95 years, all of the previous efforts have resulted in Egypt establishing an Agricultural Research Center (ARC) which has 16 research institutes, four central labs, and 36 experiment stations covering an area of 5,000 feddans. These experiment stations are distributed throughout the nation, and they cover all agroclimate zones. The ARC consists of 3,491 researchers and 28,474 support staff, distributed throughout the country.

The ARC in Egypt is using three high-technology systems to enhance agricultural development. The first system is genetic engineering to harness advances in biotechnology to support agriculture. The second system uses expert systems as a tool to optimize productivity by improving crop management. The third system uses Landsat technology for proper management of natural resources.

The tools of biotechnology, when integrated with traditional crop breeding, efficiently increase production in an environmentally sustainable manner. The increasing trend towards knowledge-intensive agriculture, particularly as it relates to biotechnology, leaves developing countries at a distinct disadvantage when competing with developed countries because of the presence of the well-established public and private technological infrastructure in developed countries, which makes them better able to accept and apply biotechnological innovations in agriculture.

Biotechnology is a set of techniques that have been developed in molecular biology that provide tremendous potential for improving crop and animal production and bioprocessing. These techniques aim at bridging species barriers to allow for genetic changes thought impossible just a few years ago. Biotechnology has been used to design and develop safer vaccines and to increase the efficiency of producing animal products that are leaner and more nutritious. It can provide new approaches to developing higher-yielding and more nutritious crop varieties, as well as improving resistance to diseases and pests. In so doing, these techniques, used in conjunction with conventional breeding programs, could make dramatic contributions to sustainable agriculture by producing improved crops that are more compatible with their environment. However, it is critical to identify new techniques that relate to problem solving rather than concentrating on the technology itself. Cell and molecular biologists are the new partners of plant and animal breeders, agronomists, and pathologists. These new partnerships must be created to ensure the integration of new techniques into agricultural research and development programs, and to demonstrate their application in the agriculture of developing countries.

To fully exploit the potential of the new tools of biotechnology to world agriculture and to ensure their transfer to developing countries, the following recommendations for international coordination are proposed:

1. Promote the preservation, collection, and characterization of germplasm essential to world agriculture.

2. Promote the training and educating of young men and women of developing nations in the field of biotechnology and related studies.

3. Enable researchers to counter problems of isolation and inadequate access to scientific literature and databases through networks of scientists in developing countries, linked to counterparts in international centers in industrial countries.

4. Provide appropriate biosafety oversights to ensure food safety, environmental quality, and preservation of natural resources.

5. Facilitate international cooperation by the industrialized and developed countries so as to make proprietary techniques, plasmids, and germplasm available to developing countries in a timely manner, while safeguarding intellectual property rights.

6. Promote the appropriate interaction between governments, industries, international research centers, and the academic community to ensure that the pipeline of innovations leads to an ever-increasing array of products for the benefit of all nations.

In developing countries it is not possible to establish a list of universal priorities for agricultural biotechnology because of several factors:

1. the varied nature of agriculture around the globe;

2. the varying degree of technological competence among developing countries;

3. constraints on crop production at different locations;

4. the difference in crop importance and problems like pests, diseases, and drought.

However, the following are examples of feasible applications of biotechnology for agriculture in the developing countries.

### *Tissue culture, including micropropagation, embryo rescue, haploid techniques, and regeneration*

Biotechnology has resulted in the development and use of hormones and nutrient media to enable recalcitrant species to be generated. This technology could be applied to most of the agronomically important species (e.g., tomatoes, potatoes, bananas, corn, cotton, wheat). Micropropagation of virus-free potato minitubers is now reaching wide commercial application in Peru, Egypt, and other parts of the developing world. Transformation and regeneration techniques have been demonstrated with rice, potatoes, tomatoes, soybeans, and a number of other crops, but increased efficiency is required to make it routine.

### *Plant disease and pest control*

One of the most successful examples involves the use of *Bacillus thuringiensis*, a soil-borne bacterium, which produces a crystal protein toxin that is insecticidal for many destructive insect pests, especially lepidopteran (moth), dipteran (fly), and coleopteran (beetle) insect families. It is being applied to tomatoes, cotton, tobacco, potatoes, corn, rapeseed, and apples in order to obtain transgenic plants that are resistant to these insect pests. These advances offer great potential benefits to developing countries, because this would lead to the minimization of the use of costly traditional chemical pesticides. Moreover, the intensive use of chemical pesticides can cause health problems and the contamination of soil and groundwater.

### *Production of virus-resistant transgenic plants*

Expression of the virus coat-protein gene in the plant genome proved to be successful in providing resistance to plants against viruses from which the capsid protein gene was isolated. Products of such advanced technology are now subject to field testing in different parts of the world. The list of such transgenic plants includes potatoes (PVX, PVY), tomatoes (TMV), squash (CMV, WMV), alfalfa (AMV), cantaloupes (CMV, WMV), cucumbers (CMV), and tobacco (TMV).

Strategies for combating plant viruses that attack major crops in the developing world could have a strong impact on agriculture in these countries.

### *Tolerance to adverse environmental conditions*

Another domain for biotechnology is the study of salt and drought tolerance, which are considered among the most serious problems in developing countries. The production of salt-tolerant strains of plants for salinized areas could be achieved by adopting nonconventional means of plant breeding.

### *Improvement of nutritional value and postharvest parameters for cultivated crops*

Attempts to increase the nutritional value of major food commodities are under way for the amelioration of seed storage proteins in grains like rice and corn and for improved oil quality and yield in rapeseed, sunflowers, and corn. Also, prolonged shelf life for tomato fruits by retarding their ripening process was made possible through the expression of the polygalacturonase antisense gene into the tomato genome.

### *Genetic mapping of tropical crops*

Application of molecular biology techniques has made available an expanded set of markers, known as restriction fragment length polymorphisms (RFLPS) that are most useful for monitoring traits that are difficult to screen, by following closely linked types of DNA through the breeding process. RFLPs can assist in manipulating quantitative traits, pathogen and parental identification, and plant propagation biology. Genome mapping can dramatically reduce the time required for any lengthy breeding program and is therefore a very useful tool for assisting plant breeders.

### *Computer expert systems*

The use of computer expert systems in agricultural extension can increase the yield and improve the quality of agricultural products. Further, they can optimize the use of water and land resources for crop production. These agro-management systems include aids for integrated crop management decisions in irrigation, nutrition, fertilization, weed control, herbicide application, insect control, and pesticide application. By using an expert system, workers can improve their performance to an expert's level, hence improving their efficiency and effectiveness.

## Landsat Technology and Agriculture

Landsat imagery is becoming extensively used in agriculture, land-use planning, and environmental monitoring. This will continue to increase as the technology advances and users gain experience with this relatively new tool. The Landsat system not only gathers the data, but also puts them into digital form for computer analysis. The high frequency of repetitive coverage over time will also allow for annual updating of information and maps.

- Settlement and urban encroachment on the fertile agriculture lands could be precisely monitored by Landsat data through its multitemporal and other privileges.

- Crop area estimation can be carried out using different Landsat images and identifying the proper dates for acquiring Landsat-computer-compatible tapes needed for each crop.

- Accurate information on land use and land cover is essential for proper planning activities, which can be obtained rapidly and accurately using remote sensing techniques.

- Landsat data can be vital for early detection of plant diseases and nutrient deficiency. Such application can be obtained through monitoring the spectral reflectance curves of the healthy and infected plants using a hand-held radiometer.

Geographic Information System (GIS) is the fundamental technology for merging various independent spatial data (maps) into a form that represents information. Within the ARC in Egypt, institutions and labs conducting research on genetic engineering, using computer expert systems in agriculture and Landsat technology in agriculture could not only serve the goals and objectives of the agricultural development plan for Egypt, but could also serve regionally via joint research programs and training.

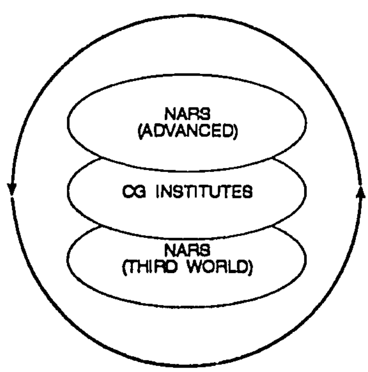



**Figure 4. Continuum**

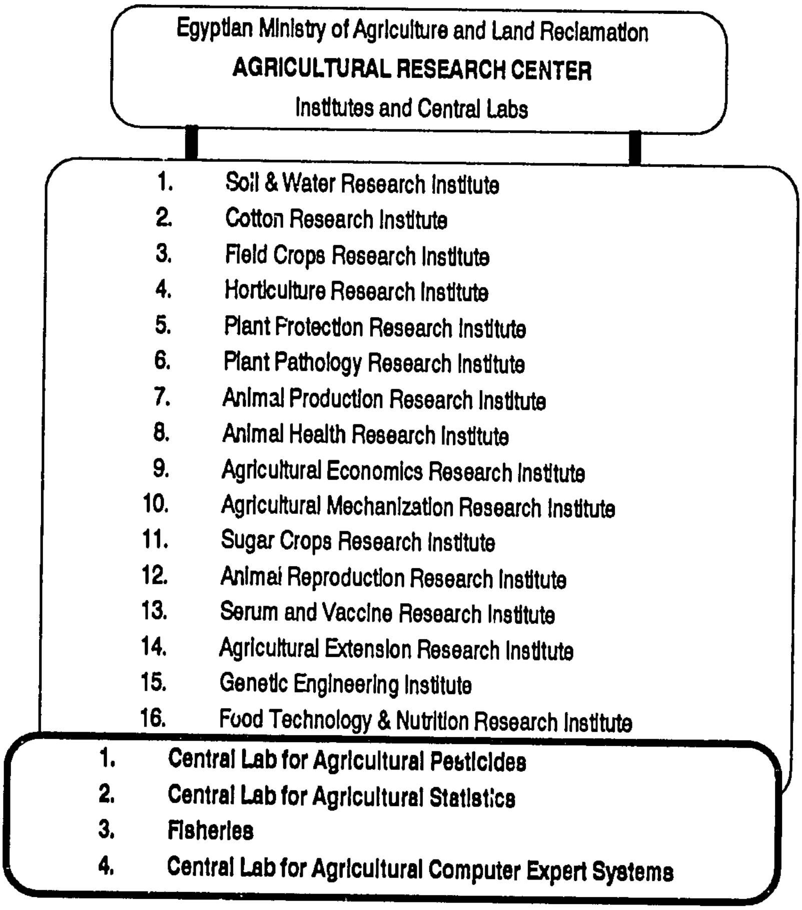



**Figure 5. Egyptian agricultural research system**

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# Institutions in Agricultural Research and the International Division of Labor: The View from Small National Agricultural Research Systems

*Mario Contreras*
Regional Pest Management Specialist
USAID/ROCAP, Costa Rica

High population growth rates, the need for increased food and export production, growing environmental degradation, and limited energy supplies are common denominators found in most developing nations. Solutions to this multi-pronged challenge need to be found within the space of a few generations. In essence, developing countries must do more, with less, in a shorter time. The alternative is widespread deterioration of life on this planet. The damage caused to the social and environmental foundations of many societies is already visible in the poorer countries. An appropriate response cannot wait for the next millennium.

With the right policy framework, small national agricultural research systems (NARS) can become an important catalytic force for economic and social growth. This paper focuses on their role, in reference to the pressing need for accelerated and sustainable growth faced by most developing nations.

## Small NARS: Definition and Factors

Defining a small NARS is like providing a universal definition of a small farmer. It is difficult to do. Fortunately, however, everybody knows one when he sees it. It is worth pointing out, nonetheless, that small NARS show significant differences in their degree of evolution. Very weak, small NARS, as well as relatively advanced ones, can be found in almost any region of the world. Furthermore, it seems appropriate at this time to highlight some of the key factors that limit their performance.

### *Inadequate policy framework*

Failures in many agricultural research and development programs can often be traced back to inadequate policy frameworks. Scientific endeavors in agriculture are seldom given high priority before competing with social, military, and political demands faced by decisionmakers in most developing countries. The level of relative investment committed to supporting agricultural research and development by small NARS is stagnant or declining. Funding appropriations and disbursements are normally mired in bureaucracy. Research and development activities are subject to political, managerial, and economic distortions. At the dawn of the new millennium, small NARS still have no constituency to elicit support for their scientific endeavors. Developing an appropriate international and national policy environment for small NARS remains an important unfulfilled goal.

### *Scarce human resources*

A common characteristic of small NARS is their scarcity of qualified human resources. Contrary to common opinion, small NARS require scientific staff of the highest quality possible. In addition, most need to increase their staffs, at least to the level of minimal critical mass. Formation of able, farsighted, agricultural research managers for small NARS should be an area of concern for national and international training programs. In-service training may be one relevant and cost-effective approach to strengthening national staff. Long-term service of research personnel is as important as their formation. Many small NARS are still bound by civil-service pay scales that drive the best scientists elsewhere.

### *Weak information management*

Information management plays a central role in research. Small NARS, in particular, must have the capacity to acquire information and materials, as needed, from the rest of the world. Ironically, information management is one of the weakest attributes of small NARS.

More and more the concept of a global scientific community seems approachable. Communication has opened unlimited opportunities for small NARS to interact with research managers from industrialized countries and other developing nations. Nonetheless, as communication technology advances on all fronts, small NARS remain plagued by inefficient information management. The cost to the developing nations in general, and to small NARS in particular, must be very high. Research networking and accessible information systems for small NARS can go a long way toward improving their performance and facilitating their scientific contributions to development around the world.

## Small NARS and Agricultural Sustainability

Unless sustainability becomes a practical down-to-earth exercise, it will remain wishful thinking, rather than the concrete development foundation it is meant to be. The following are among the contributions small NARS can make in pursuit of sustainable agricultural goals:

1. creating more complete understanding of social and economic forces, in specific agroecological contexts and human groups;

2. adapting traditional and science-based technologies to specific production and market conditions;

3. complementing interdisciplinary research programs on issues dealing with interactions between agriculture and the environment, as well as developing and adapting environmentally friendly technologies;

4. helping train-in-service the new generations of researchers needed for pursuing further development objectives and goals;

5. presenting comprehensive information and research products to different groups in ways that reach the numbers of clients needed to make a significant impact;

6. serving as links in zonal, regional, and international research networks, thus facilitating information and product flows among the various actors involved.

The destruction of the rain forest, as an illustration of a global concern, highlights the issues relative to the role of agriculture in developing nations. Such issues can best be addressed if agricultural, environmental, and social scientists participate coherently in national and international policy dialogue. Solutions to such issues will most likely demand considerable research inputs from small NARS.

## Organizing International Cooperation among NARS

It is clear that small NARS cannot do it all. Moreover, for small NARS to work in isolation is a call for technological suicide. Wider collaboration and network participation should be guiding principles for small NARS. The presence of viable collaborative regional programs may be a complementary condition for effective small NARS.

In this general context, international cooperation becomes an important factor linked to small-NARS performance in many regions of the world. Small NARS and international donors may both be best served by following a set of criteria to guide collaborative programs. For instance:

1. a sustained effort by collaborating countries to support their own research programs;

2. regional program focus and networking as vehicles for collaborative endeavors, stressing country needs and comparative advantages of participating programs;

3. client and private-sector involvement in setting research agendas and funding of collaborative and domestic research programs;

4. donor cooperation, preferentially supporting systematic, demand-driven, efficient, long-term regional collaborative modes;

5. donor assistance, preferentially conditioned to effective use of NARS resources. In this sense, private nonprofit organizations may be alternatives to traditional governmental programs and channels.

## NARS Expectations on International Agricultural Research Centers and Regional Organizations

Small NARS do not normally expect IARCs and regional organizations to substitute for their legitimate country roles. These organizations are normally perceived as complementary sources of support in planning and implementing national programs and activities. More specifically, as:

1. sources of information, research materials, and training;

2. sources of support in developing institutional capabilities;

3. linkage mechanisms to collaborative programs;

4. program continuity support (political, technical).

## The Feasibility of Small-NARS Collaboration on Export Crops

Most visible collaboration among small NARS addresses staple food commodities and related themes. There is a less apparent, but nonetheless real, ongoing collaborative effort on export crops as well. For instance, a regional network for melon crop protection has been operating in Central America for the last three years. A regional program for coffee crop improvement has also been active in that region for nearly 10 years.

Agricultural technology for export crops flows among developing countries as commercial entrepreneurs, agrichemical industry, investors, consultants, etc., participate in the export trade. In time there is as much variability in technology levels among producer groups within a developing country as there is among developing countries exporting agricultural produce overseas. Small NARS should facilitate and participate in collaborative export crop research programs.

The following conditions may positively influence export-crop collaboration among small NARS:

1. Regional collaboration is generally facilitated when regions are relatively small and contiguous, a common cultural background is shared, and technology supply is scarce.

2. Stable market demands tend to facilitate exchange when small NARS do not perceive each other as threats to domestic commercial interests.

3. A common pressing problem often triggers collaborative regional modes; e.g., a pest affecting a crop.

4. Presence of a continued stimulus provided by an external technical support program, with no commercial interest in the crop, is often a strong incentive for participating in these networks.

## Impact of New Technologies and How Small NARS Can Take Advantage of Them

Small NARS show different levels of progress and research capacity. Some small NARS have maintained particular areas of research excellence over the years; e.g., Honduras in bananas. The more-advanced small NARS have well-educated agricultural scientists, if only a few, capable of participating in new technology research programs. The concept of regional networks, with leader organizations providing the technical support and linkage to collaborative institutions, seems appropriate for the types of programs.

Biotechnology for the genetic improvement of food and export-crop species is an area in which collaborative programs with regional centers and the more-advanced small NARS could be developed. Site testing and local adaptation of new technologies and germplasm offer opportunities for extensive participation by small NARS. Integrated crop protection, including the development and use of environmentally friendly pesticides, is an approach also offering unlimited opportunity for collaboration.

Small NARS agendas have been increasing in range and complexity over the years (table 1). Concurrently, different and varied actor groups have become involved in agricultural research (table 2). In all fields of participation, it is critical for small NARS to establish research priorities based on realistic goals (table 3). Additionally, global planning and integration of efforts at the local level should be a guiding principle for all.

**Table 1. Evolving of Subject-Matter Components in the Small-NARS Agenda**

1. Disciplinary Focus: Breeding, Agronomy
2. Integrated Commodity Work: Wheat, Rice
3. Farming Systems: Interdisciplinary On-Farm Approach
4. Agricultural Diversification: Export Markets
5. Environmental Themes: Agroforestry, Biodiversity

**Table 2. Small-NARS Components**

1. Traditional Government Programs
2. Private-Sector Organizations: University, Corporation, Foundation
3. Nongovernment Organizations: Local/International NGOs
4. Producer Organizations
5. Regional Organizations
6. International Programs
7. Donors

**Table 3. Illustrative Small-NARS Potential Technological Focus**

*Expected Participation*

1. Crops and Animal Husbandry
2. Soil and Water Management
3. Integrated Crop and Animal Protection
4. Farm Management
5. Post-Harvest Technology

*Conditioned Participation*

1. Agroforestry
2. Hillside Agriculture
3. Watershed Management

*Restricted Participation*

1. Deforestation
2. Biodiversity Loss
3. Fragile Lands Deterioration

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# ISNAR and the Needs of NARS
# The Revised Strategy: Summary of Issues

*C. Bonte-Friedheim*
Director General
International Service for National Agriculture Research

## Introduction

In 1979 the Consultative Group on International Agricultural Research (CGIAR) created the International Service for National Agricultural Research (ISNAR), specifically to strengthen national agricultural research systems, or NARS. It was generally felt that strong NARS in the developing countries were a precondition for the success of the international agricultural research work and of the existing international centers. ISNAR's goal was defined as strengthening national agricultural research systems by:

- working in partnership;
- promoting sustainable institutions;
- reinforcing national capacities.

Over the years NARS have made important progress and have developed their human and capital resource base. Yet many NARS are small, others are understaffed and underfunded, and others do not use the available resources most efficiently and effectively.

ISNAR's services are directed towards the management of NARS. We aim to collaborate in the development of sustainable national institutions, improving their abilities to plan, organize, and manage agricultural research more effectively and to monitor and evaluate the progress and results.

ISNAR is an experience- and research-based service. We try to learn from the experience of different countries with different systems. Through collaborative research we adapt what we learn and develop new tools and methods for improving the management of agricultural research. We collaborate through research work, through the provision of advisory services, and through involvement in training.

## A Decade of Experience

For 11 years ISNAR has attempted the impossible: to fulfil the many different aspects of its mandate to strengthen NARS. It is an interesting mental exercise to rethink the evolution of the original ISNAR mandate. We feel that full participation of NARS leaders and a complete reflection of the specific needs of NARS (for assistance and for strengthening) are the most important inputs in defining our mandate. The existing mandate states that ISNAR's goal is to assist the developing countries in improving the effectiveness and efficiency of their national agricultural research systems through enhanced capacity in the areas of agricultural research policy, organization, and management.

Were there any attempts by the founding fathers of ISNAR to define and to limit the tasks in some specific terms, to identify the resources and to estimate time requirements for the various tasks, or to determine appropriate impact measurements of the different assignments given to the young ISNAR? If there were such early attempts, then they were certainly not fully recorded in either the original documents, the mandate, or the existing strategy.

What have been and what will be important key features of ISNAR?

ISNAR . . .

- is a service to NARS;
- is an international organization;
- offers impartial advice;
- has a clearly focused mandate;
- promotes the development of sustainable NARS.

After 10 years of existence, the second quinquennial external review was held in 1991. The team provided ISNAR with a clean bill of health. It attested that ISNAR had done very useful work and that it had established itself as an internationally accepted institute and as a valuable partner of and supporter to many NARS. We know that these views reflect the feelings in many NARS. The External Review Report also clearly indicates that the resources at ISNAR's disposal are insufficient to meet the needs — the changing needs of NARS. In the future, ISNAR will work closely with others, will seek multipliers to transfer the results of its work, and will set priorities in the selection of its partners, in the identification of its research and development topics and in the selection of topics for public information.

## The New Strategy

It has been decided that the time has come to review the existing ISNAR strategy and to present a revised strategy to the donors and some selected NARS leaders during the next CGIAR meeting in May of this year. At this policy dialogue I will introduce some highlights of ISNAR's draft new and revised strategy. This is not the time to look at what ISNAR has or has not done during the first decade of its existence. This is an opportunity to present some highlights of the new strategy, to look ahead.

Our revised strategy is based on our experience during the last five years, on what we have identified and foresee as the present and future needs of NARS, on the results of some consultations we have had with NARS leaders, with professionals from many countries, and with representatives of the international donor community. These consultations were helpful, but they can never be sufficient, and they should not be a one-time exercise. ISNAR needs annual or biennial consultations, we need to have a medium-term forward-rolling program, and we need to adjust to changes as we go along.

We are very appreciative of the opportunity to explain and to discuss our strategy and some of the important issues that we are facing. We will share with you how we have identified the strategy and how we are going to implement a program of strengthening NARS with our very limited means. Our resources are even more limited if compared to the real needs of more than 100 developing countries, from small island states, on the one hand, to large systems, on the other.

ISNAR has been very active in its first decade, increasing the quantity of its work, improving the quality of its services. It has established itself with many NARS, with many donors, and within the CGIAR system. We are confident that the results of 10 years of work will speak for themselves and that we do not need to make a case for ourselves. Others will be the advocates of what ISNAR can offer. At the same time, we look at the future based on some of the lessons we have learned and on some of the observations we have made. Some of these lessons and experiences seem very obvious, but all of them must be considered when we look at the future needs of NARS.

We have assembled the following 10 major lessons and observations which will determine our future work.

- Different NARS require different services.

- Demand will shift towards specialized advice and technical support.

- Our approach needs more flexibility if we want to meet the increasingly diverse requests.

- We need more successful collaboration in which national policymakers are engaged.
- A civil-service context limits room for maneuver.
- System and institution building is a long-term process.
- Universities have a growing role in NARS.
- Off-the-shelf management approaches can rarely be transferred directly across a range of NARS.
- More emphasis is needed on packaging and disseminating research results.

These lessons must be considered in the light of the evolving context of NARS, which can be classified under three subheadings.

First: Evolving context of NARS — the institutional and external context. Under this heading, we have selected four or five issues:

- changes in the NARS' environment;
    - policy context;
    - financial context;
- increased institutional complexity in NARS;
- developments at the regional level;
- changing CGIAR emphasis.

Second: Evolving context of NARS — the agricultural research context of the future. With regard to the future tasks of NARS, for some external observers very little has changed. Others not only note the different emphasis but see major changes in the agricultural research challenges for the 1990s and beyond. For the medium-term future, we have identified four challenges that can be considered the most important for NARS:

- expand food production to meet increasing demand;
- increase income and food self-reliance through agricultural exports;
- conserve and sustain productivity of natural resources and environment;

- promote income generation.

Third: Evolving context of NARS — scientific developments and future opportunities. In addition to these challenges there are external scientific developments and future opportunities for many NARS. These result from research and development work in other sectors or other countries. However, they can be applied for the benefit of agriculture and can make agricultural research more efficient and effective. We have selected five important fields which fall under this heading:

- biotechnology;
- new information technology;
- computer applications;
- satellite-based technologies;
- tools and methods in systems analysis.

Based on our own experience and different recent developments, it is evident that certain changes and trends will affect ISNAR and our services. First of all, the traditional definition of NARS must be modified, must be enlarged, taking into account a multiplication of actors on the national scene. Our modified definition states that NARS are "all national organizations responsible for organizing, coordinating, or executing research that contributes explicitly to the development of the country's agriculture and the sustainability of its natural resource base."

As a result of such a definition, there are future trends that will have certain implications for NARS, for their structure, organization, and management.

We have selected six future trends and their implications. These trends reflect what we consider to be important issues of NARS.

- Public research agencies, accountable to government, will need to serve as a system core to define research policy and priorities and to ensure a rational division of responsibilities.
  Implication: Sound system design and structure and effective coordination will be crucial to NARS' productivity.

- In response to research demands, the institutional makeup of NARS will become more complex.
  Implication: Government research agencies will need continued institution-building support.

- NARS will be called upon to help their countries meet multiple development objectives.
  Implication: Strategic planning and links between research and development policy will need to be strengthened.

- Growth of traditional sources of funding for NARS will be limited.
  Implication: NARS will have to give priority to increasing efficiency in resource use and to cultivating alternative sources of funding.

- Given the urgency and scope of demands, research will have to be focused on clear objectives, relevant to the needs of end users, and executed effectively.
  Implication: NARS will have to strengthen capacities for program design, monitoring, and evaluation.

- Regional research initiatives are expanding.
  Implication: NARS will need to develop policies and mechanisms for collaborating effectively with regional initiatives.

One other trend that has serious implications for NARS should be mentioned. There is a growing need for transparency, for improved accountability of public and also of private institutions. The implications are clear. NARS must account fully to the sources of support, must assume accountability for the use of often very scarce resources. Increasingly, NARS must also account for the results of their work. They will not be asked for the scientific knowledge they have accumulated. Information will be requested on the appropriate and applied outputs and technologies they have developed. In this respect, publicly funded NARS in developing countries will have to learn a lot from private-sector research and its accountability. Developing-countries' NARS are not only charged with research work and knowledge generation, but more important, they must be active in technology development. Most developing countries cannot afford to split R&D, and they lack the private sector to assure the technology development role.

Looking at these trends, then, what are the implications for ISNAR? The future key operating principles of ISNAR will not change. Accordingly, ISNAR

- seeks to learn from the experiences of NARS;

- has a service based on research and experience;

- aims to improve its service and broaden its impact by collaborating with other centers of expertise;

- has a multidisciplinary approach.

The review of the past and the definition of some major operating principles for the future will define important strategic directions in the present decade. There is no doubt that in the future ISNAR will

- diversify services;
- expand the system approach;
- increase work at the research-policy level;
- seek multipliers;
- forge strategic alliances;
- advance knowledge through research.

In the future, as in the past, NARS will remain ISNAR's principal partners. We will continue to work system-wide in diagnosis, planning, and policy analysis. While we have a certain responsibility to provide information, we must concentrate on institution building. The target group for ISNAR's institution-building work consists of

- government research organizations;
- parastatal commodity research institutes;
- research components of universities;
- research foundations.

While the target group will be very large, we have identified certain criteria that can be applied in any selection process. The criteria are accountability, public funding, importance in NARS, chances of success. ISNAR will be known by the services it will provide, by the quality of these services, and the impact of our work. We will provide three types of services:

- partnership in system and institution building;
- support for NARS in strengthening specific institutional and research-policy components;
- generation and dissemination of knowledge and information.

For each service we will need to make a number of very important decisions. These decisions are related to the following:

- key objectives;
- target client groups;
- intensity of involvement;
- outputs.

For the first service of partnership in system and institution building, we will select a small number of countries or NARS for a very intensive partnership. We will make a commitment for long-term involvement. Because the members of such a partnership will be limited, we have identified some priority criteria which include, inter alia, countries that

- have medium-sized NARS in the early stages of development or that are undertaking major reforms;
- have sought ISNAR's support at high levels of government;
- address the needs of the poor;
- have important agricultural sectors;
- need science-based agricultural development;
- exhibit the potential to implement change;
- possess the basic elements of a research system;
- demonstrate a strong policy commitment to research.

Intensive partnerships will be the result of fruitful collaboration over a number of years. ISNAR will have assembled considerable knowledge of and experience in the country and its NARS. In exceptional cases and in very large systems, a major national institute or subsystem may be identified as the potential partner with whom such a relationship can be further developed. It might be advantageous to establish such partnerships with NARS in all regions; however, other factors and priorities are more important.

The partnership will be a contractual relationship, under which ISNAR will become pro-active in highlighting necessary adjustments, possible improvements, and desirable changes in the agricultural research systems. NARS must be representative of a group of countries, not necessarily in the same region, facing similar situations. As a result of long-term cooperation with ISNAR, our partner NARS are also expected to assume a leadership role and to guide other agricultural systems, sharing their experience widely.

ISNAR will indicate and commit staff time and expertise for long-term partnerships, which will be specifically identified in an agreement, normally covering three to four years. The renewal of such an agreement will be based on a full, joint review of past impact and achievements, as well as future expectations and demand for services and ISNAR's potential for continuing the partnership. As a result of such reviews, some systems will develop into different forms of collaboration and cooperation with ISNAR, allowing new partnerships to be formed with other systems.

ISNAR expects that, depending on the number of partnership agreements and the need for such services, up to 20% to 25% of its core resources (about eight to 10 person-years) will be used for the worldwide partnership collaboration. It is expected that some of the necessary expenditure to strengthen specific NARS through intensive partnerships will be provided by the NARS themselves or might be financed by donors. The second type of ISNAR service aims to strengthen specific institutional and research policy components.

Most of the needs for the development of management tools, methodologies, and training materials will primarily result from ISNAR's collaboration with NARS. Outputs of ISNAR's work should have a very wide application and should be useful to many NARS and partners. ISNAR foresees about 40% to 45% of its core resources being applied to such program priorities.

ISNAR has identified some priority criteria for the selection of activities within this program:

- significant problem areas identified by NARS;
- number of requests for assistance;
- the need to overcome a constraint is urgent;
- improvement in the component strengthens overall performance;
- appropriate knowledge and tools not available;
- potential to collaborate with others.

While most of the needs and demands will be identified jointly by ISNAR and NARS, there will also be activities to meet the demand of other partners and collaborators. Donors have clearly identified priorities, and ISNAR and NARS must respond. The necessary work on monitoring and evaluation, and on impact assessment, are examples of this type of work.

The third type of service aims at the generation and dissemination of knowledge and information. In this service ISNAR will concentrate on agricultural research policies, on institutional development, and on sustainability of the NARS. New developments of importance to NARS in developing countries will determine the activities and the work in the service. There will be a strong demand for information. Policymakers will require advice, and they will look for trends and analysis. Not only NARS leaders, but donor representatives, and the larger community of development specialists, will all look to ISNAR for information.

It is expected that some regional priorities need to be reflected in our revised strategy. Because of Asia's share of the total global population, the limited land resources, a very large number of poor, and the technical problems of keeping production levels and even increasing yields further, it is proposed that this continent's share of ISNAR's core resources should be increased from around 20% in the last strategy to 30% for the future.

Such reallocation requires that ISNAR's concentration on Africa be somewhat reduced. While the NARS in Africa certainly need further strengthening, and the problems of African agriculture demand further research, it is hoped that non-core resources can be attracted to substitute for any core fund reduction from around 50% in the past to 40% in the future. There will be no changes in the resource allocations for Latin America or West Asia and North Africa.

The problems of allocation are of a secondary nature if the funding level of ISNAR's core budget can be increased or if sufficient special projects are allocated for strengthening NARS. The External Review has supported both approaches.

Finally, a special plea must be made for training. ISNAR needs to train NARS leaders as well as professionals who will be NARS leaders in the future. ISNAR needs to select and train its future staff and its consultants from the various regions. ISNAR needs to collaborate with other training institutions to upgrade management training in the field of agricultural research. There is considerable room to improve the efficiency and effectiveness of the NARS and their limited resources. A special plea is being made for extra resources in the field of training.

## Concluding Remarks

ISNAR has attempted to strengthen NARS and will continue to work for national agricultural research systems — overcoming the vicious circle and entering the virtuous circle. We concentrate on the threshold between the two circles. The quality of leadership, of management, of the technical content of the various programs, of the linkages of human resources, and last but not least, of political support for agricultural research, needs to be improved.

I would like to receive some views on the need for further consultations with the NARS leaders. We held a consultation with some NARS leaders from Asia in Bangkok. We had a large number of individual consultations with NARS leaders and donor representatives. We also used some regional and national workshops to explain our future strategy. We are still debating about the need to have some other regional consultations. Unfortunately, two major meetings of NARS leaders for Africa and the Near East planned for December last year had to be canceled. We will present the revised strategy to our Board for approval in early April and then take it to the CGIAR in May.

Strengthening the NARS in the developing countries and the improvement of their organization and management reflect a general concern of the international community. Once the weak NARS have become strong, efficient, effective, and self-sustained institutions, once they can fend for themselves and have established national and international links and collaboration, then a special support program will no longer be needed. At that time the core of ISNAR's present mandate and program will disappear. The other important ISNAR tasks of research work to develop new and appropriate management tools and methodologies can be taken over and absorbed by existing strong national and international institutes or organizations in developing and developed countries. Similarly, the public information function on the state of NARS and on agricultural research development must be done. At the present time, ISNAR combines this with other tasks and has accepted the responsibility for it in the short run. In the long run, we must evaluate the resource commitments and the opportunities to institutionalize it both in the South and in the North.

The development of NARS in developing countries is being constantly monitored by ISNAR. At the present time, the new demands for agricultural research results and the necessary involvement of agricultural researchers in many nonresearch activities are growing fast. At the same time, the institutional sustainability of agricultural research in many countries seems to weaken. Unfortunately, the gap seems to widen between the strong and the weak NARS.

Not only ISNAR itself and the quinquennial external reviews, but also others will periodically or constantly analyze the situation and inform the NARS and the donor community of developments and new needs of strengthening the agricultural research systems in developing countries. In the future, the various reports hopefully will indicate a declining justification for a special program to support NARS in developing countries. Once the NARS in developing countries and the donors agree on the termination of a special support program, ISNAR itself will be proud of the manifold contributions it will have made by then to strengthening NARS and to supporting efficient and effective agricultural research at the national, regional, and global levels. The revised strategy will lead the way towards that goal.

# Workshop Conclusions and Recommendations

*Howard Elliott*
Deputy Director General
ISNAR

In presenting the summary report, Dr. Howard Elliott recalled that the objective of the workshop had been to engage in a policy dialogue between policymakers and research leaders. It was inspired by the need for a strong global agricultural research effort, based on strong national research systems, to meet the challenges of the new millennium. Presentations had been structured around the idea that policies, technological opportunities, and institutions must interact if we are to achieve growth, alleviate poverty, sustain production resources, and safeguard the environment. Success cannot be achieved if any one of these is ignored.

The final plenary session brought together the principal ideas discussed during the workshop, concentrated on defining roles in the emerging global research system, and made specific recommendations to the actors present.

There was general consensus on the following points:

- The emerging global research system is being driven by a number of trends, which include the following:
  - political and economic integration at both the global and regional levels;
  - a broadened agenda requiring research solutions;
  - the growing maturity of NARS;
  - changes in science and information technology;
  - the need to include new institutions in the research process.

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*Note:* A summary of the presentations and discussions of the workshop can be found in the companion publication, "Highlights of a Policy Dialogue: Future Challenges for National Agricultural Research," published by ISNAR in March of 1992.

- The revised agenda for the global research system will require adjustments in institutional structures, mechanisms, and policies on the part of all participants and stakeholders in the system, including the donors who fund it. New partnerships and alliances will have to be formed.

- The common task of all those present is to produce innovations that serve clearly defined goals, not just to carry out research per se. This requires the creation of an enabling environment for technology development and adoption. Attention must be given to the entire system and its linkages, since agricultural research cannot be separate from (and perform better over the long term than) the environment in which it works.

- The CGIAR system is recognized as a small part of the global research system and of research focusing on developing countries. It should not be seen as an aid organization or as a vehicle for passing resources through to national systems. Its long-term vision calls for it to work on research of a global nature and to produce "international public goods." Its evolution towards this goal depends on the existence of strong national research systems. It must function as an excellent research system and should not be called upon to perform tasks for which it does not have a comparative advantage.

- Regional entities and regional mechanisms, emerging from the bottom-up demand of national systems, are playing a role in the transition to the long-term vision of the CGIAR.

- There is a need for structures and mechanisms to harmonize the roles of the actors in the system. These will involve changes in the *internal* operating style of NARS, regional entities, the CGIAR, international centers, and donors, as well as accommodations in the way they *interact* with each other.

- Not all NARS and regions are homogeneous. The structures and mechanisms developed must take this into account so that there are no "orphans" in the global system.

## Recommendations

The final plenary discussion generated a number of specific recommendations for each of the participants present at the meeting. These are summarized below.

### *Specific recommendations for NARS and national policymakers*

- Create a capacity to influence the policy dialogue on issues like intellectual property rights, GATT negotiations, and domestic policies influencing the success of technology generation and adoption.

- Recognize that donors deal with sovereign governments, and these must ultimately assume responsibility for the agreements they make.

- Recognize the special characteristics of research in responding to structural adjustment pressures. Be prepared to use structural adjustment to make the necessary adjustments in the research system but do not let blanket measures destroy long-term research and break up productive research teams. How restructuring is implemented is an internal policy debate.

- Be innovative in seeking new sources of funding at national and regional levels. This involves analyzing potential sources of taxation and the incidence of taxes on incentives and efficiency, as well as revenue.

- Strengthen linkages with national universities. Help the educational system mobilize support for its needs and redefine its role in relation to agricultural research.

- Strengthen collaboration with other NARS.

- Assert control collectively and individually over the agenda of networks and other entities purporting to serve NARS.

- Build a scheme into project design to evaluate the impact of research.

***Specific recommendations for regional programs and organizations***

- Create structures and mechanisms that ensure that programs are guided by the NARS they serve.

- Assist NARS in harmonizing their policy objectives and creating the enabling environment in which they work.

- Take leadership in subregional roles of technical service and harmonizing policies of a transnational (but regional) nature.

- Ensure that the role of facilitator is not one of gatekeeper to the region.

- Ensure institutional stability by remaining small in size so that resources are not diverted from NARS.

***Specific recommendations for the CGIAR and TAC***

- Ratify the long-term vision of the CGIAR system. Make sure that the productivity objective is not unduly discounted in the priority-weighting scheme used in strategizing. The task of feeding eight billion people by the year 2025 will still require strong attention to production.

- Ensure better representation of NARS in the guidance and governance of the CG system. This includes consultation with subregional organizations as representatives of NARS, if NARS cannot be consulted individually.

- Review relations between IARCs and NARS and the ways they can be improved.

- Encourage individual IARCs to serve as catalysts between NARS and their sources of funding.

- Participate with NARS in informing and influencing policymakers on technological policy issues.

***Specific recommendations for ISNAR***

- Update and increase the flow of information to research leaders and policymakers about NARS.

- Advise NARS on the implications of structural adjustment policies and help them demonstrate to policymakers the long-term danger of institutional instability and loss of human capital resulting from shortsighted policies.

- Assist NARS in master planning for research at the national level.

- Develop methodologies for planning in a regional context, stressing the complementarities among NARS.

- Help NARS manage change.

- Adopt a clear strategy towards the development and use of partner organizations and individuals as "multipliers" of ISNAR's impact.

***Specific recommendations for donors***

- Develop funding mechanisms that will facilitate the sharing of responsibilities in the changing global system. Donors must collaborate. Multilateral and bilateral sources of funding must come together to encourage partnerships among institutions working at the global, regional, and national levels.

- Strengthen regional funding mechanisms to facilitate partnerships among NARS and their collaborators.

- Earmark a fixed percentage of agricultural development projects to research, not only to include support for research for a project's immediate needs, but also to provide for the results that development will require in later years.

## Closing Remarks

**Dr. Jean Ndikumana**, speaking for the African participants, expressed the hope that ISNAR would continue to give strong priority to the region, that the recommendations of this dialogue would serve as guidelines for action, and that they should be disseminated widely to research leaders and policymakers. He stressed the importance of continued collaboration with ISNAR in priority setting, establishing institutional mechanisms for involving users in research planning, developing national agricultural research master plans in each country, and strengthening networks.

**Dr. Shen Jinpu** underlined the importance of policy issues. For the Asian region, cost-reducing technology and research to increase the value-added in agriculture were taking on particular importance. The larger Asian NARS could make strong contributions in biotechnology, while building on their strength in conventional research. However, he noted that regional collaboration remained weak and called for partners in international research to help foster greater collaboration among NARS. Training at the postdoctoral level will continue to be a priority, as will training the next generation of NARS leaders in management. He encouraged ISNAR to do more in the Asian region, concentrating on assistance in developing and applying new management methods, undertaking studies of experience in the region, and sharing this knowledge among NARS. Through partnerships in the region, both ISNAR and the NARS can learn and share.

**Dr. Mario Contreras** noted that our discussions confirmed that we share a common objective. However, regions and subregions are different and respond to external forces in different ways. The liberalization of trade generates needs for new and different technologies. Large NARS in Latin America are moving to assume responsibilities previously ensured by international centers. Small NARS are accentuating their collaborative alliances. And all NARS will need to manage change and become more entrepreneurial.

**Mr. Hussein Faraj** emphasized that West Asia and North Africa need agricultural research. The task is for research leaders to market their product better and to convince policymakers of the need for research and their interest in supporting it. This would require permanent mechanisms for a dialogue between researchers and policymakers. This meeting had demonstrated the value of such a dialogue.

**Dr. Christian Bonte-Friedheim** recalled the three possible crises he mentioned in opening the workshop. Our deliberations confirmed that there is no justification for complacency. He thanked the participants for making this a South-South dialogue and the resource persons for helping this to come about. He expressed the hope that research would be both wanted because it is needed and needed because it is wanted. In thanking the German Government and DSE for their collaboration, he looked forward to a future dialogue in similar circumstances two years hence which would help keep the issue of support to developing countries high on the agenda of the developed countries.

**Dr. E. Kruesken**, on behalf of DSE, felt that associating a policy dialogue with Green Week was a good idea. The exposition demonstrated the results of research at the consumer level and the importance it has played in the exports of the developing countries represented. DSE will continue to play its part in strengthening research by organizing dialogues of this type that can help develop a constituency for research among developed-country taxpayers. It will continue to use its skills in organizing and facilitating conferences to bring this about.

In closing the workshop, **Major-General Majid Ul-Haq, Minister of Agriculture for Bangladesh**, described how he had come to the decision to devote a full week to attend this dialogue. The communications gap between research and policymakers and between North and South needs to be bridged. Such an event has proven the value of organized dialogue on how policy formulation can interact with technical matters. In formally closing the meeting, he expressed the hope that ISNAR would collaborate even more intensely with national systems and that international agencies would provide ISNAR with the resources to meet the expectations of the NARS.

# Appendix A
## *Participants*

| | | |
|---|---|---|
| **ABDALLAH,<br>Anna Margaret** | Minister of State<br>in the Office of the Prime<br>Minister<br>P. O. Box 70032<br>Dar-es-Salaam, Tanzania | Phone: (255) 51 37059 /<br>27733<br>Telex: 53159 owm tz<br>41503 pmo tz |
| **ANDERSON,<br>Dr. Jock R.** | Principal Economist<br>World Bank<br>Agriculture & Rural<br>Development Department<br>Agricultural Policies Division<br>1818 H St, NW<br>Washington, DC 20433, USA | Phone: (1) 202 473-0437<br>Fax: (1) 202 334-0568<br>Telex: rca 248423 |
| **BAHARSJAH,<br>Prof. Sjarifuddin** | Junior Minister of Agriculture<br>Department of Agriculture<br>Jalan Harsono, Room #3, Pasar<br>Minggu<br>P. O. Box 83/12001/kbypm<br>Jakarta 12550, Indonesia | Phone: (62) 21 780-4166,<br>Fax: (62) 21 780-4237<br>780-4337<br>Telex: 44246 / 44332 |
| **BOKELOH,<br>Dr. Georg** | University of Göttingen<br>Reinholdstrasse 3<br>D - 3400 - Göttingen<br>Federal Republic of Germany | Phone: (49) 551 770-1935 |
| **BONTE-FRIEDHEIM,<br>Dr. Christian** | Director General<br>ISNAR<br>P. O. Box 93375<br>2509 AJ The Hague<br>The Netherlands | Phone: (31) 70 349-6100<br>Fax: (31) 70 381-9677<br>Telex: 33746<br>Cable: isnar |
| **BUSCH,<br>Dr. Rolf** | Ministry of Food, Agriculture<br>and Forestry<br>Agricultural Research<br>Department<br>Postfach 140270<br>D - 5300 - Bonn 1<br>Federal Republic of Germany | Phone: (49) 228 5291/<br>529-3301<br>Fax: (49) 228 529-4262<br>Telex: 886884 |
| **CHRISTIANSEN,<br>Bernd** | University of Hohenheim<br>Institute of Agricultural<br>Economics in the Tropics (490)<br>D - 7000 - Stuttgart 70<br>Federal Republic of Germany | Phone: (49) 711 459-3326 /<br>459-3392 |
| | Gaisgasse 27<br>D - 7024 - Filderstadt<br>Federal Republic of Germany | Phone: (49) 711 705-129 |

| | | |
|---|---|---|
| **CIRIO, Dr. Felix Manuel** | Chairman<br>Instituto Nacional de Tecnología Agropecuaria (INTA)<br>Rivadavia 1434<br>Casilla Correao 276<br>1033 Buenos Aires, Argentina | Phone: (54) 1 389-5932 / 389-5200<br>Fax: (54) 1 111-917 |
| **CONTRERAS, Dr. Mario** | U.S. Agency for International Development: Regional Office for Central American Programs (USAID/ROCAP)<br>US Embassy<br>Apartado 825 — 1200 Pavas<br>San Jose, Costa Rica | Phone: (506) 317-473 / 317-479<br>Fax: (506) 317-476 |
| **DE HAAS, Dr. H. Jochen** | Ministry for Economic Cooperation (BMZ)<br>Agricultural Section<br>Postfach 12 0322<br>D - 5300 - Bonn<br>Federal Republic of Germany | Phone: (49) 228 535-1 / 535-222<br>Fax: (49) 228 535-202 |
| **DORJI, Dasho Leki** | Deputy Minister of Agriculture<br>Ministry of Agriculture<br>P. O. Box 252<br>Taschichho-Dzong<br>Thimphu, Bhutan | Phone: (975) 22129 / 22726 / 22545 / 22230<br>Fax: (975) 23184 (DASA) *or* 23153 (MOA)<br>Telex: 890 221 magfo tpu bt<br>Cable: agri ministry thimphu |
| **EL-BELTAGY, Prof. Dr. Adel** | Director<br>Agricultural Research Center<br>Ministry of Agriculture and Land Reclamation<br>Gema'a Street<br>Giza, Egypt | Phone: (20) 2 702-442<br>Fax: (20) 2 712-061 *or* c/o nagel: 629-519<br>Telex: 20332 fcri un |
| **EL-KUWAIZ, Dr. I. Abdullah** | Associate Secretary-General Economic Affairs<br>The Cooperation Council for Arab States in the Gulf<br>P. O. Box 7153<br>11462 - Riyadh, Saudi Arabia | Phone: (966) 1 482-9344 / 482-7777<br>Fax: (966) 1 482-7716 / 482-9089<br>Telex: 2 03 635 tawini sj |
| **ELLIOTT, Dr. Howard** | Deputy Director General<br>ISNAR<br>P. O. Box 93375<br>2509 AJ The Hague<br>The Netherlands | Phone: (31) 70 349-6100<br>Fax: (31) 70 381-9677<br>Telex: 33746<br>Cable: isnar |
| **EMMERIJ, Dr. Louis** | President<br>Organisation for Economic Co-operation and Development (OECD)<br>Development Centre<br>94, rue Chardon-Lagache<br>75016 Paris, France | Phone: (33) 1 452-48290 / 452-48292<br>Fax: (33) 1 452-47943<br>Telex: 620160 ocde paris |

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|---|---|---|
| **FARAJ,**<br>**Dr. Hussein** | Director General<br>Institut National de la<br>Recherche Agricole (INRA)<br>B. P. 415<br>Rabat R.P., Morocco | Phone: (212) 77 70955 / 72642<br>Fax: (212) 77 70049 |
| **FLETCHER,**<br>**Alan M.** | 300 Forest Home Drive<br>Ithaca, NY 14850, USA | Phone/Fax: (1) 607 257-4359 |
| **GERSTER-BENTAYA,**<br>**Maria** | Alte Dorfstrasse 14A<br>D - 7000 - Stuttgart 70<br>Federal Republic of Germany | Phone: (49) 711 457-128 |
| **IDACHABA,**<br>**Prof. Francis S.** | Vice-Chancellor<br>University of Agriculture<br>Private mail bag 2373<br>Makurdi, Nigeria | Phone: (234) 44 33488 / 33204 / 33205<br>Telex: 85304 |
| **JALLOW,**<br>**Dr. A.Tijan** | Director General<br>Institut du Sahel (INSAH)<br>B. P. 1530<br>Bamako, Mali | Phone: (223) 222-148<br>Fax: (223) 222-178<br>Telex: insah 432 |
| **JINPU,**<br>**Dr. Shen** | Chinese Academy of<br>Agricultural Sciences (CAAS)<br>30 Bai Shi Qiao Road / Lu Xijiao<br>Beijing 10081<br>People's Republic of China | Phone: (86) 1 890-851<br>Fax: (86) 1 831-6545<br>Cable: 4878 |
| **KRÜSKEN,**<br>**Dr. E.** | German Foundation for<br>International Development<br>(DSE)<br>Center for Food and Agriculture<br>(ZEL)<br>Postfach 20<br>D - 8133 - Feldafing<br>Federal Republic of Germany | Phone: (49) 8157 380<br>Fax: (49) 8157 38227 |
| **LANTIN,**<br>**Dr. Manuel** | Assistant-Secretary for<br>Research, Training and<br>Extension<br>Department of Agriculture<br>ATI Builidng Floor 3, Elliptical<br>Road<br>Diliman, Quezon City 100<br>The Philippines | Phone: (63) 2 998-741 / 998-946<br>Fax: (63) 2 980-726<br>Telex: (752) 27726 |
| **LANZENDÖRFER,**<br>**Dr. Matthias** | Am Weissen Steine 5<br>D - 3400 - Göttingen<br>Federal Republic of Germany | Phone: (49) 551 43343 |
| **MAKHUBU,**<br>**Prof. Lydia** | Vice Chancellor<br>University of Swaziland<br>Kwaluseni Campus<br>P/Bag Kwaluseni, Swaziland<br>Southern Africa | Phone: (268) 84011 / 84121 / 85108 / 85264<br>Fax: (268) 85276<br>Telex: 2087 wd<br>Cable: uniswa |

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|---|---|---|
| **MCCALLA, Dr. Alex F.** | Chair<br>Technical Advisory Committee, CGIAR<br>University of California<br>219E Street, Suite 2C<br>Davis, CA 95616, USA | Phone: (1) 916 752-8648 / 752-8649<br>Fax: (1) 916 752-8572<br>Telex: 4900010239 ucd ui |
| **NDIKUMANA, Dr. Jean** | Director General<br>Institut des Sciences Agronomiques du Burundi (ISABU)<br>B. P. 795<br>Bujumbura, Burundi | Phone: (257) 223-390<br>Fax: (257) 225-798<br>Telex: 5147 |
| **ODHIAMBO, Prof. Dr. Thomas Risley** | Director<br>International Centre of Insect Physiology and Ecology (ICIPE)<br>P. O. Box 30 772<br>Nairobi, Kenya | Phone: (254) 2 802-501 / 802-503 / 802-509<br>Fax: (254) 2 803-360<br>Telex: 22053 icipe 25066 dudu |
| **PARDEY, Dr. Philip** | Senior Officer<br>ISNAR<br>P. O. Box 93375<br>2509 AJ The Hague<br>The Netherlands | Phone: (31) 70 349-6100<br>Fax: (31) 70 381-9677<br>Telex: 33746<br>Cable: isnar |
| **PERRAULT, Dr. Paul T.** | Senior Officer<br>ISNAR<br>P. O. Box 93375<br>2509 AJ The Hague<br>The Netherlands | Phone: (31) 70 349-6100<br>Fax: (31) 70 381-9677<br>Telex: 33746<br>Cable: isnar |
| **PERSLEY, Dr. Gabrielle J.** | Biotechnology Manager<br>World Bank (IBRD)<br>Agriculture Technology and Natural Resources Division (AGRTN)<br>Agriculture and Rural Development Department<br>1818 H Street, NW<br>Washington, DC 20433, USA | Phone: (1) 202 473-0353<br>Fax: (1) 202 334-0568<br>Telex: rca 248423 |
| **PETERS, Prof. K. J.** | Institut für Tierproduktion<br>Technische Universität Berlin<br>Fachbereich Internationale Agrarentwicklung<br>Lentzeallee 75<br>D-1000 - Berlin 33 (Dahlem)<br>Federal Republic of Germany | Phone: (49) 30 3147-1100 / 3147-1110<br>Fax: (49) 30 3147-1426 /<br>Telex: 18 42 62 tublnd |

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|---|---|---|
| **PETIT,**<br>**Dr. Michel J.** | Director<br>World Bank<br>Agriculture and Rural<br>Development Department<br>Sector Policy and Research<br>1818 H Street, NW<br>Washington, DC 20433, USA | Phone: (1) 202 473-0340 / 334-0568<br>Fax: (1) 202 334-0568 / 473-0340<br>Telex: 44 00 00 98 197688 / 64145 |
| **RABBINGE,**<br>**Prof. Dr. Ing. Roelof** | Head<br>Department of Theoretical<br>Production Ecology<br>Agricultural University<br>Wageningen<br>P. O. Box 430<br>6700 AK Wageningen<br>The Netherlands | Phone: (31) 8370 82141 / 70 356-4449<br>Fax: (31) 8370 84892 |
| **REID,**<br>**Dr. Janice C.** | Regional Representative<br>Caribbean Agricultural<br>Research and Development<br>Institute (CARDI)<br>University campus<br>Box 113<br>Mona, Kingston, 7 Jamaica | Phone: (1-809) 92-71231 / 92-71661<br>Fax: (1-809) 92-72099 |
| **RUNGE,**<br>**Dr. C. Ford** | Professor<br>Department of Agricultural and<br>Applied Economics, and<br>Department of Forest Resources<br>University of Minnesota<br>Center for International Food<br>and Agricultural Policy (CIFAP)<br>332 Classroom Office Bldg<br>1994 Buford Avenue<br>St. Paul, Minnesota 55108, USA | Phone: (1) 612 625-9208 / 625-8713<br>Fax: (1) 612 625-6245 |
| **SCOTT,**<br>**Dr. Bruce** | Deputy Director General<br>International Council for<br>Research in Agroforestry<br>(ICRAF)<br>P. O. Box 306 77<br>Nairobi, Kenya | Phone: (254) 2 521-450<br>Fax: (254) 2 521-001<br>Telex: 220 48 icraf nbi |
| **SÖTJE,**<br>**Dr. Peter** | Deputy Director General<br>German Foundation for<br>International Development<br>(DSE)<br>Rauchstrasse 22<br>D - 1000 - Berlin 30<br>Federal Republic of Germany | Phone: (49) 30 26062<br>Fax: (49) 30 2606-380<br>Telex: 181615 dseb d<br>17308120 desbln ttx d |

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|---|---|---|
| **STEINACKER, Dr. Günter** | German Agency for Technical Cooperation (GTZ)<br>Division 423<br>Postfach 5180<br>D - 6236 - Eschborn<br>Federal Republic of Germany | Phone: (49) 6196 79-1427<br>Fax: (49) 6136 79-115<br>Telex: 407501-0 gtz d |
| **SUGIYANTO, Dr. Wahyudi** | Agricultural Attaché<br>Mission of the Republic of Indonesia to the European Communities<br>7, Avenue Tedesco, Box 3<br>B-1160-Brussels, Belgium | Phone: (32) 2 675-3500 / 675-3424<br>Fax: (32) 2 675-3261<br>Telex: 20397 putri b |
| **TRIGO, Dr. Eduardo** | Director Program II<br>Technology Generation and Transfer<br>Instituto Intermericano de Cooperación para la Agricultura (IICA)<br>P. O. Box 55<br>2200 Coronado, Costa Rica | Phone: (506) 290-222<br>Fax: (506) 294-741<br>Telex: 2144 iica |
| **UL-HAQ, Major-General (Ret.) Majid** | Minister of Agriculture and Irrigation<br>Water Development and Flood Control<br>Government of Bangladesh<br>29 Minto Road<br>Dhaka, Bangladesh | Phone: (880) 2 241911 / 404282<br>Telex: 642218 Aagri bj |
| **VEELBEHR, Engelbert** | Program Leader<br>German Foundation for International Development (DSE)<br>Center for Food and Agriculture (ZEL)<br>Postfach 20<br>D - 8133 - Feldafing<br>Federal Republic of Germany | Phone: (49) 8157 38215<br>Fax: (49) 8157 38227 |
| **WETTASINGHE, Dr. D. T.** | Executive Secretary<br>Sri Lanka Council for Agricultural Research Policy (CARP)<br>269, Galle Road<br>Colombo 3, Sri Lanka | Phone: (94) 1 575-636 / 574-119<br>Fax: (94) 1 575-636 / 580-721 / 449-280<br>Telex: 215 37 metallix ce<br>21424 agmin ce |

# Appendix B
## *Schedule of Activities*

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|---|---|---|
| **Sunday, January 12, 1992** | Informal Welcome<br>Cocktail Evening | |
| **Monday, January 13** | The Challenges Facing World Agriculture and the Role of Agricultural Research | Chairperson: *Felix Cirio*<br>Rapporteur: *Howard Elliott* |
| 09:00 – 09:45 | Formal Opening<br>*The Honorable H. P. Repnik* | |
| 09:45 – 10:00 | Response of Organizers:<br>*Peter Sötje* (DSE) and *Christian Bonte-Friedheim* (ISNAR) | |
| 10:00 – 10:30 | Coffee | |
| 10:30 – 10:45 | Workshop Objectives and Program Outline<br>*Engelbert Veelbehr* and *Paul T. Perrault* | |
| 10:45 – 11:05 | First Keynote Address:<br>The Long-Term Vision<br>*Louis Emmerij* | |
| 11:05 – 11:15 | Discussant: *Francis Idachaba* | |
| 11:15 – 11:35 | Second Keynote Address: The Role of Research in the Global Agricultural Development Challenge: An International Perspective<br>*Michel Petit* | |
| 11:35 – 11:45 | Discussant: *Hussein Faraj* | |
| 11:45 – 12:05 | Third Keynote Address: Agricultural Requirements and the Role of Research: A View from a NARS<br>*The Honorable Sjarifuddin Baharsjah* | |
| 12:05 – 12:15 | Discussant: *Janice Reid* | |
| 12:15 – 12:45 | Discussion | |
| 12:45 – 14:00 | Lunch break | |
| 14:00 – 18:00 | City Tour | |
| **Tuesday, January 14** | A Policy Perspective on the Sustainability of Production Environments | Chairperson: *Anna Abdallah*<br>Rapporteur: *D. T. Wettasinghe* |

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| 09:00 – 09:30 | Toward a Land Theory of Value<br>*C. Ford Runge* | |
| 09:30 – 09:45 | Discussant: *Leki Dorji* | |
| 09:45 – 10:15 | NARS Trends and Structure of Support<br>*Philip Pardey* | |
| 10:15 – 10:30 | Discussant: *Kurt Peters* | |
| 10:30 – 11:00 | Coffee | |
| 11:00 – 12:10 | Plenary Discussion | |
| 12:10 – 12:20 | Introduction to the Visualization Approach<br>DSE moderators | |
| 12:20 – 12:30 | Clarify tasks of working groups | |
| 12:30 – 14:00 | Lunch break | |
| 14:00 – 18:00 | Working Groups on Policy Issues | |
| **Wednesday, January 15** | Scientific Advances and Agricultural Technologies as Opportunities for NARS | Chairperson:<br>*Adel El-Beltagy*<br>Rapporteur:<br>*Philip Pardey* |
| 09:00 – 10:00 | Presentation of Working Group Reports from Tuesday | |
| 10:00 – 10:30 | Overview and Introduction to Technology Assessment<br>*Jock Anderson* | |
| 10:30 – 11:00 | Coffee | |
| 11:00 – 12:40 | Presentation of Four Examples of Opportunities and Issues in New Technologies | |
| 11:00 – 11:40 | Biotechnology<br>*Gabrielle Persley* | |
| 11:20 – 11:40 | Pest Management<br>*Thomas Odhiambo* | |
| 11:40 – 12:00 | Forestry and Agroforestry<br>*Bruce Scott* | |
| 12:00 – 12:20 | Computer Satellite Applications<br>*Roelof Rabbinge* | |
| 12:20 – 12:30 | Clarify terms of reference of working groups | |
| 12:50 – 14:00 | Lunch break | |

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| 14:00 – 14:15 | Review specific tasks of working groups | |
| 14:15 – 18:00 | Working groups on technology issues | |
| | Evening Candlelight Dinner Hosted by ISNAR | |
| **Thursday, January 16** | Institutions for Agricultural Research and the International Division of Labor | Chairperson: *Francis Idachaba*<br>Rapporteur: *Abdullah El-Kuwaiz* |
| 08:30 – 09:30 | Presentation of working group reports from Wednesday | |
| 09:30 – 09:50 | Long-Term Vision of the CGIAR<br>*Alex McCalla* | |
| 09:50 – 10:00 | Discussant: *Lydia Makhubu* | |
| 10:00 – 10:20 | Regional Organizations<br>*Eduardo Trigo* | |
| 10:20 – 10:30 | Discussant: *Tijan Jallow* | |
| 10:30 – 11:00 | Coffee | |
| 11:00 – 11:30 | Plenary Discussion | |
| 11:30 – 12:00 | ISNAR and the Needs of NARS<br>*Christian Bonte-Friedheim* | |
| 12:00 – 12:15 | Discussant: *Hussein Faraj* | |
| 12:15 – 13:00 | Plenary Discussion | |
| 12:30 – 14:00 | Lunch break | |
| 14:00 – 14:20 | Large NARS: The Implications of Scientific Advances and New Technologies on Research in the Developing Countries<br>*Adel El-Beltagy* | |
| 14:20 – 14:30 | Discussant: *Manuel Lantin* | |
| 14:30 – 14:50 | The View from Small Agricultural Research Systems<br>*Mario Contreras* | |
| 14:50 – 15:00 | Discussant: *Jean Ndikumana* | |
| 15:00 – 16:00 | Plenary Discussion | |
| 16:00 – 16:20 | Changing and Coffee | |
| 16:20 – 17:00 | Travel to the International Conference Center | |

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| 17:00 | Reception: *Mayor of Berlin* | |
| 18:00 | Formal Opening of Green Week | |
| **Friday, January 17** | | |
| 08:00 – 11:00 | Ministers' walk around the Green Week exhibition | |
| 12:00 – 14:00 | Lunch: for selected guests — with German Minister of Agriculture | |
| | Institutions for Agricultural Research and the International Division of Labor (continued) | |
| 14:00 – 17:30 | Plenary Discussion | Chairperson: *Lydia Makhubu*<br>Rapporteur: *Paul T. Perrault* |
| **Saturday, January 18** | Public Session | Chairperson: *Majid Ul-Haq*<br>Rapporteur: *Paul T. Perrault* |
| 09:00 – 09:20 | Conclusion and recommendations of workshop<br>*Howard Elliott* | |
| 09:20 – 09:30 | Response from African NARS<br>*Jean Ndikumana* | |
| 09:30 – 09:40 | Response from Asian NARS<br>*Shen Jinpu* | |
| 09:40 – 09:50 | Response from Latin American NARS<br>*Mario Contreras* | |
| 09:50 – 10:00 | Response from WANA NARS<br>*Hussein Faraj* | |
| 10:00 – 10:15 | Formal Closure:<br>*Christian Bonte-Friedheim* | |
| 10:15 – 11:00 | Coffee | |