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THE CHANGING DYNAMICS OF GLOBAL AGRICULTURE

A Seminar/Workshop on Research Policy Implications for National Agricultural Research Systems

DSE/ZEL Feldafing,
Germany,
22-28 September 1988

ISNAR

DSE

CTA

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

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

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

ISNAR is supported by a number of the members of CGIAR, an informal group of approximately 43 donors, including countries, development banks, international organizations, and foundations.

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A Seminar/Workshop on Research Policy Implications for National Agricultural Research Systems

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DSE/ZEL Feldafing
Germany
22-28 September 1988

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International Service for National Agricultural Research (ISNAR)
The Hague, The Netherlands

German Foundation for International Development (DSE)
Feldafing, Federal Republic of Germany

The Technical Centre for Agricultural and Rural Cooperation (CTA)
ACP-EC Lom Convention
Wageningen, The Netherlands

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Foreword

Developing countries have commited substantial investments to improve their agricultural research capacities during the last two decades. However, there are indications of declining growth in the support for research. Moreover, while some of the national agricultural research systems (NARS) are still in the organizational stage, many are experiencing second-generation problems of policy, structure, and management, which require careful analysis and appropriate action.

In addition, recent trends in world agriculture, such as food surpluses in many developed countries amidst persistent food deficits elsewhere, increasing concern for sustainable agricultural environments, increasing internationalization of agricultural research, and increasing participation of the private sector in research, are creating new conditions that have important implications for both agricultural policy and agricultural research policy.

Global trends in agricultural development affect countries in different ways according to their geography, resource endowments, institutional capacities, and policy environments. Nevertheless in an increasingly interdependent world, policy decisions taken at a national level both influence and are influenced by external decisions. This is a true for agricultural research policy as for development policy.

Agricultural research institutions in developing countries have to keep pace and continually adjust to the dynamic domestic and external environments in which they operate. They need to make sound institutional strategic choices not only to cope, but to effectively manage change. The national research leaders who must make those decisions need to be fully informed of the key variables which influence those strategic choices.

To address these issues, the three cosponsors, 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) of the ACP-EEC Lome Convention, agreed to organize a workshop on agricultural research policy. It was held in the Food and Agriculture Development Center of DSE in Feldafing, Bavaria, Federal Republic of Germany, on 22-28 September 1988. The seminar brought together key national research leaders and policy-level decision makers from developing countries, and leading scientists and policy analysts from the global research community.

The workshop had five formal objectives:

- to identify recent global trends in agriculture and their research policy implications;
- to highlight the interrelatedness of agricultural developments in different countries of the world;
- to bring into focus the important relationships among macro development policy, agricultural development policy, and agricultural research policy in providing an environment conducive to the development of agriculture;
- to provide a forum for leaders, decision makers, and policy analysts in the global agricultural research community to exchange views on these issues;
- to establish an agenda for future research and collaborative activity on agricultural research policy issues.

The workshop was organized along four major themes:

- food surpluses and their research policy implications;
- inking growth in agriculture with growth in the rest of the economy;
- sustainability of agricultural production environments;
- mobilizing and sustaining support for agricultural research.

Food Surpluses and Their Research Policy Implications

Food surpluses in Western Europe and North America, as well as in some developing countries, have been building up during the last 10 to 15 years. The reasons for these surpluses include rapid technological progress and domestic policies highly favorable to agriculture. These huge surpluses eventually enter the international market and depress global commodity prices; thus, adversely affecting production in a number of developing countries. On the other hand, some of the poorest developing countries experience chronic food deficits. Low prices, including the availability of these surplus commodities as food aid, allow the most underprivileged sectors of the populations of these countries to have access to food they otherwise could not afford.

Quite obviously, these surpluses and deficits have national and international economic, social, and political implications. In the long run, these developments call for major adjustments in agricultural policy and in the structure of agriculture itself, both in developed and developing countries. Concomitantly, there will be adjustments in agricultural research policies as well.

Linking Growth in Agriculture with Growth in the Rest of the Economy

A common premise in national development planning is that agriculture will provide the engine of growth to the country's economy. That expectation has yet to materialize in many countries. Very often the broader economic, social, and political environment constrains the development of agriculture itself. Where some progress has been achieved in agriculture, such gains have not manifested themselves in growth in the nonagricultural sector.

The impact and dependence of agriculture on other sectors, while appreciated, seem not to be too well understood in the agricultural research communities in many developing countries. All too often these considerations do not appear to influence the way research is organized and the manner in which priorities are set and resources allocated.

Sustainability of Agricultural Environments

In the relentless pursuit of production to meet ever-increasing domestic and export demands, environmental considerations have taken a back seat in agricultural planning and development, often with disastrous consequences.

In many parts of the world, the sustainability of agriculture itself has been compromised by severe degradation of the environment. Agricultural research needs to be increasingly oriented to resource management, in addition to, or apart from, the current conventional commodity research.

Mobilizing and Sustaining Support for Agricultural Research

Encouraged by the successes of the Green Revolution, many governments invested substantially in their agricultural research infrastructure during the last two decades. However there are increasingly disturbing signs of declining domestic support. Moreover, during the period of rapid expansion, some governments, often with donor encouragement and support, established infrastructures beyond their capability to sustain.

There is now an increasing realization among donors that their well-meaning, but independent initiatives are unduly competing for scarce national scientific, managerial, and material resources. Frequently, objectives are not satisfactorily achieved.

Private-sector research is increasing in importance in many parts of Latin America and Asia. This is expected to intensify as modernization progresses, as more and more countries adopt more market-oriented development policies, and as new biotechnologies find agricultural applications. This phenomenon calls for a review of policy as well as of institutional arrangements in agricultural research.

The NARS must find their niches in the emerging global research system described by Vernon Ruttan. They must strengthen their linkages among themselves, with the international centers, with universities, and with developed country institutions in order to contribute and to exploit more fully the evolving global system for their national needs.

Mobilizing support for agricultural research rests squarely on the shoulders of NARS leaders, and is one of their principal roles as managers and leaders. The key appears to be how to establish credibility among the clients and stakeholders of research. Sharing of relevant national experiences should prove useful.

Each of the main topics was introduced by plenary presentations followed immediately by brief discussions. Detailed discussions of the key issues were conducted in the small working groups that were organized after the plenary sessions. The working group results were reported back in plenary, where further debate continued. The individual group reports and plenary discussions are consolidated in the session summaries in this volume

The workshop benefited greatly from the DSE participatory discussion approach described in the annex. The contributions of the five DSE moderators, namely, Manfred Häbig, Uwe Krappitz, Adelheid Kückelhaus, Matthias Lanzendörfer, and Thomas Schwedersky, are gratefully acknowledged.

Planning and organizing the workshop was the responsibility of the organizing committee, which was composed of Emil Javier, Howard Elliott, and Ulf Renborg from ISNAR, Klaus Klennert from DSE, and Werner Treitz and T.M. Narain from CTA.

Seth Beckerman and Kathleen Sheridan edited copy and prepared the manuscripts for publication.

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Ladies and gentlemen, distinguished guests:

On behalf of the German Foundation for International Development, I have the pleasure to welcome you to this international workshop on *The Changing Dynamics of Global Agriculture: Research Policy Implications for National Agricultural Research Systems*.

Before going a bit into the contents of this workshop, allow me a few minutes to introduce to you the Deutsche Stiftung für International Entwicklung, abbreviated DSE.

DSE, the German Foundation for International Development, is a private organization with a staff of about 400 people, which is financed by the federal and state governments of the Federal Republic of Germany. Its task is to contribute to the international exchange of experience on development problems and their solutions.

Our philosophy is that human resources development is the key to development; without developing human resources all attempts to accelerate the development process are to fail. With respect to development assistance, personal assistance is for us an important means of collaboration, which can sometimes be more efficient than many measures of financial and technical assistance. Or to say it differently: only a table standing on three stable legs – financial, technical, personnel collaboration – will be a really stable table!

Accordingly, the foundation has organized international conferences, seminars, and training courses for more than 60,000 people in the last 26 years, most of whom have come from the Third World. Presently the annual number of participants from developing countries is about 8000.

More than 60% of DSE's activities relate to on-the-job training of post-graduate professionals from Africa, Asia, and Latin America. Most of the training is done in the developing countries themselves, but it is also conducted in the Federal Republic of Germany and other industrialized countries.

Another DSE activity is the country-oriented preparation of German professionals who are going to serve in projects of our bilateral programs of technical and economic cooperation. DSE is also responsible for providing development policy documentation and information, as well as teaching materials for the different target groups.

Last – but certainly not least – DSE is responsible for preparing and organizing international and national conferences, seminars, workshops, and expert meetings for the exchange of knowledge and experience to help solve different kinds of development problems. In doing so, one of its aims is to mediate between science and policy on the one hand, and science and practice on the other hand. This is also one of our intentions in supporting this workshop.

Agriculture is a basis of livelihood for all mankind, but in particular in developing countries where major parts of the population still depend on agriculture as their main source of income.

Agriculture seen from a global perspective has become a dynamic force, especially in the last decades. Due to their agricultural policies, this has caused food surpluses in North America and Europe based upon high subsidies and a strong distortion of the domestic markets which have not only led to affluent nutrition in these countries, but have disturbed the markets in many developing countries.

In developing countries, population growth combined with the rapid urbanization has led to an enforced need for higher agricultural production. To fulfill this need, research was called upon. The international research community, in cooperation with the national research systems in developing and developed countries, did a terrific job of raising the agricultural production in Asia and Latin America, and to a lesser extent also in Africa.

The reasons for these differences in development are manifold. Undoubtedly, the national agrarian policies – such as prices and credit policies – are of strong importance to explain the national differences in agricultural production. But certainly one can learn from the achievements in Asia and Latin America that successful implementation of research results needs good infrastructure development connected with industrial development. It was said years ago that development has to stand on two feet – and the movement of these feet has to be coordinated to joint complementary activities. Only if the intersectoral linkages are well established can a constant growth in agricultural production be achieved and the social consequences of this modernization process be kept to a tolerable level for those affected.

In fact, in a few developing countries, there have been food surpluses in certain years and with special products. But mostly the situation is still characterized by a rather poor nutritional standard for many parts of the population in the Third World, so one should be cautious not to overestimate the effects of these few surpluses, because politicians in developed countries might easily draw misleading conclusions.

With raising agricultural production as a goal, not only an intensification of agricultural production took place, but also an extension of the area under cultivation. Both, but in particular the latter, have often led to ecological problems which, in some areas, already have destroyed the basis of agricultural production. So the call for the sustainability of agriculture has become more and more vigorous, and it seems this will become the major aim in the long run.

Here again, research is called upon to help solve the problem of higher agricultural production without destroying the ecological base of agriculture and with improving the standard of living. And because research needs support to fulfill this task, the international donor community is called upon as well.

Global food surpluses with regional food deficits, intersectoral dependencies, and the threat of irreversibly destroyed environments are major dynamic factors which have to be taken into account when drafting research policy for the next decades.

Research policy needs thinking ahead of the actual developments. So this workshop offers a platform for you outstanding personalities to think ahead and formulate the necessary research policy recommendations and priorities, and to show realistic ways and means to have them implemented. ISNAR, in particular Dr. Emil Javier and Dr. Howard Elliott, deserve our gratitude for taking the lead in drafting and designing this workshop in such an excellent way. We would like to thank CTA for its support, in particular Dr. Treitz, who unfortunately could not attend our workshop, and Dr. Narrain. And, of course, we would like to express our appreciation that all of you have come such a long way to take part in this workshop. Such an excellent pool of knowledge which is gathered here makes me sure that this workshop will be a success.

Alexander von der Osten
Director General
International Service for National Agricultural Research
The Hague, The Netherlands

Let me start my words of welcome by paying tribute to our hosts -- the German Foundation for International Development (DSE). We thank our friends at DSE for their hospitality in hosting this event, their collaboration in organizing the program, and their warm welcome here at Feldafing. They have provided us with the setting for a pleasant and highly productive meeting. Let us make use of it.

It is a pleasure for me to extend to you a cordial welcome on behalf of ISNAR as one of the three cosponsors of this workshop. My greetings go to a diverse group of people that have assembled here to work together:

- NARS leaders and policymakers from developing countries;
- research leaders, researchers, and policymakers from the industrialized world;
- representatives from international development agencies (FAO and IICA);
- representatives of bilateral development assistance agencies (CIRAD and GTZ);
- a colleague from a sister organization in the CGIAR (IFPRI);
- our collaborating partners from the cosponsors (DSE and CTA);
- in short, friends and colleagues interested in the issues before us.

Let me say a few words about this meeting -- its historical perspective, its organization and sponsorship, and my expectations about the outcome and results.

Historical perspective. This workshop is loosely linked to a long-standing tradition: a series of annual policy seminars organized by Vernon Ruttan at the University of Minnesota. These seminars brought together scientists, policymakers, and development assistance people from both developing countries and the industrialized world. The seminars were appreciated for the relevance of the topics and the mix of the audience. While there are historical links, this workshop is different. It differs in organization, sponsorship, thrust, and expected outcomes.

Organization and sponsorship. This is a workshop – not a seminar. Emphasis is on interaction and participation: on working together on a common agenda towards a common objective.

The event is organized and sponsored jointly by three partners: DSE, CTA (the Technical Centre for Agricultural and Rural Cooperation of the EEC/ACP Lomé Convention), and ISNAR. This partnership works well. We are different, we have different objectives, mandates, and skills, and we complement each other. What is important is that we share a common goal – to contribute towards technological progress for development in the developing world

Results and outcome of this workshop. I have three things in mind:

- A set of practical conclusions tha will be useful to both NARS leaders and policymakers as they make decisions on the future orientation of agricultural research, the direction of technology development, and their priority choices guiding the allocation of scarce resources – in short, pratical guidelines for research policy formulation.

- A set of recommendations about the practical implications of all this on NARS. Here, I look at policy, organizational, and management aspects of NARS – the factors that largely determine NARS productivity.

- An action agenda on some specific issues for NARS, and for those of us who work with NARS in support of their objectives.

My emphasis is on practical results that NARS leaders can use in their decision making. The range of participants assembled here should guarantee precisely that: a focus on practical results. NARS leaders present here will ensure that in our discussions we capture the real issues – as seen from their perspective. To facilitate this, the workshop focuses on the broader context and policy environment in which NARS are working.

Choice of topics. Our agenda is ambitious. We face four major topics:

- food surpluses and their research policy implications;

- linking growth in agriculture with growth in the rest of the economy;

- sustainability of agricultural production environments;

- mobilizing and sustaining support for agricultural research.

A central theme cutting across our deliberations this coming week relates to the productivity and sustainability of NARS – the productivity and sustainability of national technology-generation capacities in the developing world. As you well know, this subject is close to our heart at ISNAR.

We see as our central task to assist developing countries in their efforts:

- to strengthen their NARS;
- to increase the productivity of their NARS (through enhanced capacities in the areas of research policy, organization, and management);
- to increase the flow of resources to agricultural research and technology generation.

We know, of course, that productivity of a research system and its capacity to generate commitment and mobilize funding are closely related.

That linkage resembles a chicken-and-egg situation:

- research needs adequate support to be productive and offer solutions to technological problems of its client groups, but at the same time,
- a NARS needs to be productive and show results to generate support. It needs to "sell".

In the course of this workshop we shall look at both sides of the equation. We shall do this from two perspectives, global and regional.

We shall ask ourselves:

- How can we help African NARS to increase the productivity of their research systems? What can we do to sustain the recent growth of their systems?
- How can we help some of the Asian research systems overcome the second-generation problems they are presently facing?
- What can we do to stabilize the support for Latin American NARS – to reduce the effects of fluctuations, and past and present cycles of support levels.

I am confident that jointly we shall find answers and contribute some practical solutions. My colleagues and I look forward to working with you.

T.M. Narain
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It is an honor and a privilege for me, on behalf of the Technical Centre for Agricultural and Rural Cooperation (CTA), to thank you all for your presence at this workshop. For the benefit of those present here who are not well acquainted with CTA, I would like to say a few words about the role and activities of the Centre.

The initials CTA are derived from the French title *Centre Technique de Cooperation Agricole et Rurale*. The Centre has had its headquarters in Ede-Wageningen in the Netherlands since 1984. It was conceived during the negotiations of the Second Lomé Convention, which is a series of cooperative arrangements between the 12 member states of the European Community and 66 states of Africa, the Caribbean, and the Pacific (ACP). Thus the Centre is a joint EC-ACP institution established within the agricultural cooperation chapter of the Lome Convention.

Its specific purpose is to facilitate the access of ACP states to information on agriculture required for their agricultural and rural development.

The Centre is not a research organization, and therefore is not a source of knowledge and information. It relies on research organizations and other institutions that generate knowledge and results. CTA's goal is to assist and enhance the flow of agricultural information systems.

CTA collaborates with existing organizations to provide up-to-date agricultural information to ACP citizens to enable them to make informed choices about the options for agricultural and rural development.

The Centre is engaged in these activities:

- question-and-answer service;
- assistance to document centers and libraries;
- studies;
- publications;
- workshops and seminars.

Question-and-Answer Service

Because the Centre is at the disposal of ACP states to provide information about agriculture and rural development, the Centre had to have a question-and-answer service.

Publications

However, because the Centre is very young, it did not wait for questions to arrive, but was actively engaged in stimulating ACP nationals by informing them of the existence of the Centre and of the potential benefits they could derive from it. To do this, it launched the bimonthly information bulletin *SPORE*.

Publishing is an important activity of CTA. Among CTA's publications are proceedings of workshops, studies undertaken on behalf of CTA, joint publication of manuals with well-known publishers, and translation of important books and bulletins which are available in only one language.

Studies

CTA finances a few studies on areas of concern to a group of countries in a region or for the ACP group as a whole; these include agroforestry, food trends, and compilation of directories of information sources.

Workshops

CTA believes that workshops provide opportunities for the staff responsible for agricultural and rural development in the various countries to meet and become better acquainted so that they may communicate more freely and with confidence. Workshops are occasions for exchanging general experience, as well as for further discussions on specific topics. The discussions become a compilation of up-to-date knowledge on the topic, which can subsequently be synthesized and made available to all concerned.

CTA is contributing to the financing of this workshop with this idea in mind. The results of the sessions can serve as background for planning future activities so that they recognise the global issues involved in the formulation of national agricultural research systems.

I would like, on behalf of CTA, to thank the organizers very much for the excellent arrangements made for the workshop, and DSE in particular for providing the venue.

I wish us all a successful workshop. Thank you very much.

Expectations of the Ministry of Economic Cooperation

R.D. Schurig
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I wish to convey to you all the good wishes of the Federal Minister for Economic Cooperation, Mr. Hans Klein. He is taking part at present in the annual World Bank meeting, which as you know, takes place this year in Berlin. Even though our meeting here does not quite have the same number of participants as the Berlin meeting – there are at the moment some 10,000 people assembled in Berlin – I feel nevertheless that the subject we are dealing with deserves priority within the scope of development cooperation. We are discussing the status and tasks of national research today, and even more so, in the future. The importance of the subject is underlined by the fact that we have three institutions responsible for this workshop.

Another subject is the responsibility to be attached to agricultural research in developed countries, as well as to the international agricultural research centers, for agricultural development, and also the development of national research in Third World countries. Finally, we must accept jointly the challenges to agricultural science in the years to come.

The great importance of past research for agricultural development processes is demonstrated not only by the example of agriculture in the industrial countries, but in a number of Third World countries as well.

The pressure which a growing population quite often places on soil reserves to ruthlessly pursue production increases, and the related danger of other damage to natural resources, is of increasing concern. Securing food and nutrition by a country's own efforts is no longer possible everywhere. Increases in agricultural production, despite and perhaps because of the widespread deployment of operational inputs and technology, may have reached the limits of what is ecologically acceptable, here as well as in many developing countries. To ignore these limits would, in the long run, destroy the basis of existence for future generations.

For a long time agricultural production increases have been the key task of international and national agricultural research, which culminated in the Green Revolution with its undisputed success. The high degree of food self-sufficiency that was attained in the countries of Asia and parts of Latin America — which formerly had been thought impossible — is an outstanding achievement. Today, the preservation of natural resources is a dominant theme, and is of importance to developing sustainable production while using natural possibilities to increase yields. This applies especially to marginal areas and the arid zones in Africa. Helplessly, we have had to accept that increasingly poor soil, spreading of the steppe, and desertification are the consequences of deforestation and subsequent unadapted production methods.

The prevention of such ecological damage is, in economic terms, perhaps of much greater importance than possible local production increases and profits. This represents a challenge to agricultural research, and at the same time, a responsibility which this research cannot evade.

The German Federal Government has been supporting international agricultural research for more than 15 years with ever-increasing contributions. These contributions today amount to a total of DM 290 million.

No doubt, international agricultural research centers have done remarkable work in the scientific sector. However, the results could have been even better and in some cases, more demand oriented, if cooperation between the national and international agricultural research institutes had been closer. This is particularly true for national research in African countries. The gap will widen further in the future as international agricultural research increasingly adopts methods of biotechnology and gene technology.

Research cannot be done in isolation, but must remain related to the operational level. In the final analysis, it is a service for the farmer, and this is the understanding which governs its financing. If research results were not practical they would indeed be too expensive. I think that neither donors nor Third World countries would be able to afford such luxury.

National research is the link between international research and the extension services. Both are of equal necessity. Problems connected with changes in research priorities and a growing world population can be resolved only if all concerned agree on the priciples. However, due to a lack of (or inadequate) institutions and a shortage of qualified personnel, many developing countries can not make full use of science and research as an integral part of their development efforts. It is important, therefore, to strengthen our partners where necessary, so that they will be able to fulfill their roles.

The donor countries, and the governments of the recipient countries as financiers, are called upon to act accordingly.

Of equal importance are partnerships and scientific exchange between institutes and universities in the developing and the industrial countries. In many developing countries, national researchers require not only technical equipment and advice, but they must also be given the feeling that they are independent equal partners within the framework of the overall task, who are in fact indispensable. I think all this is well known and has been reflected in the setting up of various institutions and programs. Let me just mention in this connection CTA, ISNAR, ICRA, and the activities of SPAAR within the scope of international agricultural research. Many bilateral and private programs and institutions, and also training institutions like DSE, also serve to strengthen national research.

I have been asked about the expectations the German Federal Government has about this workshop. The subjects that are being dealt with here, and the many well-versed participants are, so to speak, a guarantee for up-to-date and profound results. The expectations I have are in fact quite simple. I want to prevent this workshop from sharing the fate of many events of this nature, namely to come up with many good recommendations which, for a variety of reasons, will later on be simply filed away, and not be translated into practical work.

One might say, of course, that an exchange of ideas alone was worth the meeting. This is certainly true. But we should not be content with only that. Let us make recommendations which are practical and likely to be implemented. We have competent representatives from CTA, ISNAR, and SPAAR who can help us do this. Furthermore, we have representatives from national research institutions who can give us useful hints about how their countries and regions view the problems. Our aim should not be to put forward maximum demands, but to propose what is feasible. With this in mind I wish the meeting much success.

Expectations from a National Research Director

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On behalf of my peers, distinguished leaders of national agricultural research systems and decision makers, I wish to express to the three sponsoring organizations our deep appreciation and heartfelt thanks for providing us the unique opportunity to participate in this profound – one is almost tempted to predict *historic* – international workshop held in this beautiful setting.

We have all perused the background information provided on the issues to be discussed, the quality of participants, and the structuring of the workshop, and we were delighted to confirm once more the wisdom, the organizational skills, and the standards of excellence of the sponsors. We were deeply impressed with the breadth of scope, the substance, the interrelatedness, the universality, and the urgency of the issues to be addressed.

Let me cite and briefly comment on them:

- food surpluses in several countries amidst persistent food deficits in others, and their research policy implications;
- sustainability of agricultural production environments;
- linking growth in agriculture with growth in the rest of the economy;
- mobilizing and sustaining support for agricultural research.

The status of food adequacy is distinctly different between developing and developed nations. As a rule, developing nations face a problem of persistent food deficits while surpluses are the privilege of developed nations. In this regard it must be considered that famine currently threatens large numbers of people in Africa, while millions of people in Asia and Latin America face extraordinary food shortages in the wake of natural calamities or civil strife. Food consumption per person, which has been declining in a large number of developing countries throughout this decade, decreased further in all developing regions in 1987, indicating a tragic rise in the number of hungry people. More children are now suffering from malnutrition than a decade ago. According to United Nations estimates, over 14 million children under the age of five die needlessly every year from malnutrition and disease in the developing countries.

This disparity and these trends deeply concern the international community and should have implications for agriculture and food policies and for agricultural research policies.

There are serious signs of deterioration of agricultural environments which more often plague developing countries, but to some extent also developed countries. Such disastrous developments include deforestation, soil erosion, desertification, loss of land to other uses, and erosion of plant genetic resources, while intensified management systems are often accompanied by environmental pollution from excessive fertilizer use and indiscriminate pesticide applications.

Such environmental degradation poses a threat to the food security of present and future generations. Consequently, it is essential to pursue sustainable global food security through production systems which safeguard the natural resources and protect the environment.

One notes with concern that the extreme poverty of the rural populations and population pressure in many developing countries are among the major causes of environmental degradation. Exploitation such as excessive cultivation of slopes and overstocked rangelands cause serious losses of soil and water resources.

It is possible, however, to increase agricultural productivity without land degradation. With environmentally sound agricultural management and land-use planning, which take into account the specific conditions of different countries, many problems can be corrected before they become crises — possibly irreversible ones with serious consequences for the sustainability of agricultural environments and food security. It is prudent that environmentally sound agricultural management practices form an integral part of national food strategies, and that environmental concerns are integrated in economic development policies and programs.

Environmentally sound agricultural development programs, integrated into comprehensive development strategies, should receive sufficient attention when resources are allocated, while increased national and international support should also be provided to research which promotes sustainable agricultural environments and food security in developing countries.

The common premise in national development planning that agricultural gains and development will necessarily promote the growth of other sectors in a country's economy, or the reverse situation, that gains in nonagricultural sectors will result in agricultural growth, is often not substantiated by the facts. It is therefore necessary to harmonize and converge policies, including agricultural research policies, so that gains in one sector of the economy are translated into gains in other sectors, and in this way the economy as a whole is enhanced.

Mobilizing and sustaining support for agricultural research is a topic that touches the heart of all agricultural research leaders. And the session on this topic viewed from different angles and perspectives is appropriately one of the richest with no less than eight contributions. It will be difficult even to cite the titles of the papers, much less the issues to be discussed, by a multitude of leading international scientists, policy analysts, and national agricultural research leaders.

It might be more appropriate to touch on the rationale of this session, and I do it drawing heavily on the background information.

There was a substantial investment in agricultural research in developing countries in the last two decades, but such support has been diminishing in recent years. The establishment of infrastructures beyond the foreseeable needs of countries, and beyond their capacity to sustain them, were contributing factors, as well as an increasing realization among donors that their initiatives should be coordinated and priorities ranked so that they would not compete for scarce national, scientific, managerial, and material resources.

This session will focus attention on major second-generation problems confronting national systems, along with views from eminent professionals of ways to deal with them successfully.

Many factors point to an increasingly interdependent world, to the increasing need for integrated approaches, and to the need for the development of coordinated policies at national and international levels. Food surpluses in many countries, amidst persistent food deficits in others, policies linking agricultural growth with growth in the rest of the economy, sustainability of agricultural production environments, and mobilizing and sustaining support for agricultural research, are all profound issues. They confront – although in a different manner – both developed and developing countries.

I feel very privileged to have the opportunity to participate in such a challenging conference. I look forward to an intellectually stimulating working environment, and to listening and interacting with eminent colleagues, international scientists, and policy analysts in molding the thoughts which should prevail in formulating rational, integrated, and environmentally sound agricultural research policies in our home countries.

Session I

Food Surpluses and Their Research Policy Implication for Developing Countries

Agricultural Policies and Research Priorities

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Introduction

The organizers of this seminar suggested the title of this paper – global food surpluses and their research policy implications. I have chosen a different title, however, because surpluses (and deficits) in agricultural markets are nothing more than the visible consequences of distortions in markets caused by policies.

Instead of focusing on the outward appearance of the issues, I will emphasize the close link between the policies pursued by all nations, each with its own objectives, and the imbalances in the global distribution of food. The character of those policies must be highlighted, together with their effects within countries and on each other through international markets.

At the same time there is the need to describe the chain of causes and effects which link surpluses on one end of the scale to the priorities for agricultural research. It is a long chain in which national policies are one element, the related patterns of agricultural development a second, their implications for world trade a third, and the consequences for food security a fourth. Obviously, current policies are not immovable, but can and will be changed, bringing changes which affect both world markets at one end and people's food security at the other. It compels one to look at alternative scenarios and to ensure that research priorities are established within a framework of expected policy changes.

Being at some distance from agricultural research, I cannot claim to know what programs and achievements characterize that work. This makes me hesitant to pronounce on research priorities. Some of my suggestions may be found less useful, already part of priority programs, or unacceptable for other than economic reasons.

A Policy Perspective

Not all countries in the world are self-sufficient in food. Some are net importers, others net exporters. Over time, net importers become net exporters or the reverse (UNCTAD, 1987). Looking at it from a commodity perspective, the picture is even more complex because countries import some food items and export others. Against that background, what can be said about imbalances? In that context, what is considered an imbalance?

International trade makes all of this possible; countries exchange goods and services in competitive markets. Countries will engage in international trade when they expect to profit from exports or to save on resources through imports. Ever since the early 19th century, classical economic theory and analysis have centered on this basic notion, which is known as the concept of comparative advantage. It is at the root of international specialization or the distribution of labor (Soderstein, 1971; Viner, 1938). The fact that countries exchange food and other goods and services in international markets cannot be deplored on the ground of imbalances, even though some countries are net importers or exporters. In fact, these international relations are desirable, reflect efficient use of resources, contribute to specialization, and thus to increased welfare in the world. In a world economy without barriers to trade and without distorted national economic policies, that is, in the ideal world of liberalism, no country would be or even want to be, self-sufficient in anything. Trade and world prices would govern the optimal allocation of resources and, thus, the national patterns of trade and production.

Imbalances reflect policies and their effects on resource use, production, trade, and consumption. In the ideal liberal world, markets and prices will offset the threat of imbalances, restore the equilibrium of supply and demand at a specific price, and send a signal to producers and consumers to bring their actions into harmony again. The point of equilibrium differs with and without policy intervention. And it is that difference, and the effects it has on other countries as a consequence of a policy step by one trading country, which is critical to a discussion of imbalances.

Ideal liberal world not feasible

The ideal liberal world without interventions is not feasible, and stating this basic thesis has some rather significant consequences. No country in the world can afford to be without a minimum of public services and public regulation. Apart from an army and police force, a number of services are by their nature monopolistic, and therefore require regulation in the public interest, such as electric power, the telephone service, or drinking water supply. But these services and regulatory activities must be financed. Governments have a range of options to mobilize the required services, and each alternative has implications for the behavior or markets (Parikh et al., 1988). Indirect domestic taxes raise prices and reduce consumption, taxes on imports have a protective effect on domestic producers, and income taxes may reduce savings and investment.

Whatever choice is made, distortions are unavoidably inflicted on the economy. If two countries which export the same commodity make different choices to finance the same level of domestic public services, their competitive position is liable to be affected, with one country gaining a larger export market share at the expense of the other. There are no international rules to prescribe in what way national governments should finance their domestic public services, nor about what constitutes an essential public service and what its level should be. No economist, let alone politician, would want to defend the thesis that nations should do without some minimum of basic public services and regulation. Implicitly they accept the argument that there cannot exist an economy free from policy-induced distortions.

The consequence is that discussions concerning liberalization, deregulation, and privatization are discussions about alternatives which are recommended to improve present, imperfect situations. The ideal is not a practical alternative because any policy impacts markets and the real variables in the economy.

Intervention to stabilize domestic prices

In addition, it is questionable whether free markets do in all cases maximize welfare, particularly with unpredictable agricultural production due to weather variations (Mellor and Raisuddin, 1988). With imperfect foresight, production decisions by farmers are based on price expectations which may in practice be belied by actual price developments. Farmers may incur costs for being wrong and, for small farmers in particular, these costs may be beyond what they can afford. As a consequence, they choose production patterns which limit their risk, even if this implies on average a lower income.

Farmers insure against excessive fluctuations in their income, and pay for it by a lower average income. At issue then, is the question whether on average higher incomes could be reached if the risks that farmers try to avoid were shared by more people. Sharing among all farmers is one approach, but it is certainly not the most attractive alternative because all farmers face the same basic risks, although some can afford them more than others. The real issue is whether it makes economic sense to share the risks with consumers and taxpayers, instead of leaving them entirely to farmers.

On this issue the views are certainly not uniform among economists. A substantial number, particularly those closely involved with agricultural development policies, take the view that there is economic merit in risk-sharing in which a risk-neutral government takes the lead and adopts a policy which reduces the risk of risk-averse farmers. When the government guarantees stable prices to farmers, their production decisions are no longer influenced, or are at least less influenced, by risk-avoiding behavior, and their production will as a consequence become higher, with higher average incomes over the years.

But there are offsets: a government which adopts a price policy for agricultural products, even if the domestic price is set at a level reflecting current and expected world market prices, also adopts the consequence that it subsidizes imports in years of high world prices, or exports when world prices are low. Conversely it may reap windfall gains when importing at low or exporting at high prices. Even if these cancel out over time, government expenditures are destabilized, and efforts to compensate these fluctuations through countermeasures affecting other expenditures may reduce the economic attractiveness of investments in nonagricultural sectors. On the positive side, these measures will increase agricultural production and probably will also improve the balance of payments through larger exports and/or import substitution.

The argument concerning risk leads to the argument that policies designed to reduce domestic price fluctuations below world market price fluctuations can improve welfare, compared to an open market. It constitutes an economically acceptable basis for government intervention to stabilize domestic prices. It does not provide an argument for setting domestic prices differently from the average or the trend of world market prices: international prices remain the guideposts that in the long run ought to be followed in setting domestic prices. We will return to this issue: in reality many countries engage in price policies that do not heed this rule.

So far, it has been noted that government policies will always exist, because in all countries there is a consensus about some package of public services and their financing, both of which lead to changes in demand/supply balances and market prices. In addition, a case is made for economically justified intervention to dampen the effects of international price fluctuations on the domestic market, specifically for agricultural products. A third area is the government's role in providing rural infrastructure, particularly its role in land development.

Rural investments by the public sector

One might argue that rural public investments are part of the public services discussed earlier. But this is not so clear cut in the case of land development: leveling, terracing, improving water management, or land consolidation. In most cases these investments are undertaken for private lands to improve productivity in ways that are beyond the capability of the owners or users themselves. It changes the value of the assets directly, enhancing the income-generating capacity of those assets and the tax base of the government. But even if one argues that these investments belong to the category of standard public services, there is still reason to discuss these government activities as a separate issue because they have profound implications for agricultural development.

Governments undertake a large part of these investments because it would neither be possible, nor efficient, if farmers were to do this by themselves. Without investments of this kind, farmers are hemmed in by the prevailing natural conditions and therefore have a limited choice of cropping patterns and crop technologies. Generally speaking, farmers are more constrained when land is not developed, whereas their risks are highest when land is not level, not protected against erosion, and not provided with the means to manage the water regime.

Cropping patterns respond to changes in expected net revenues per hectare more readily in areas where land is in an advanced stage of development (Bhalla et al., 1984). New technologies which affect expected net revenue are adopted mainly in those areas, and not in regions that lack the means to control water. Two different questions lead to different arguments about technological progress in agriculture. One addresses the scope for technological change in agriculture, given the existing levels of land development. This leads to farming systems research and the identification of the constraints governing prevailing production patterns, usually concluding that farmers have rather small margins for change and adoption. The other question addresses the scope for new investments in land development and the possible effects on the adoption of new technologies. The first is an essentially static approach, but attractive as an extension of the agronomic research undertaken by international and national research institutes. The second is a dynamic approach at the level of investment planning which is clearly beyond the scope of agronomic research, but at the same time very important as an activity crucial to technological progress.

The issue of imbalances as a function of government policies can and should therefore be extended to government investment policies in rural infrastructure, and specifically to land development programs. Differences from country to country, both in terms of what the present generation inherited and current land development activities, are quite large. Efforts by governments to ease the constraints imposed on farmers by their natural environment fundamentally determine agricultural growth and national food markets.

Dynamics of land development

What determines the scale of a government's efforts to improve the land base? Opportunity is undoubtedly one factor, sadly lacking or small in some countries, abundant in others. Need is another, when a growing population and the risk of ever-increasing food imports point to the high priority of land development. Whether these investments are always economically sound, even if they are technically feasible, is a matter of considerable debate, particularly in sub-Saharan Africa. Although the question is relevant in terms of allocating scarce resources, there is always the lingering suspicion that much of the cost-benefit analysis of land development programs leaves a lot to be desired in terms of benefit assessment in particular. That suspicion is made stronger when looking at past land development activities which have resulted in highly productive agricultural activities in regions which today would be considered too expensive to develop. My home country, the Netherlands, is such an example.

The history of land development therefore causes one to be rather careful in the use of the comparative advantage concepts. In a static sense it may have a lot to say about a country's pattern of trade, but investments in infrastructure and public amenities, including those related to land development, may change comparative advantage over time. The safest statement to make is that the process is as yet not well understood. In turn, this suggests that a somewhat liberal attitude in undertaking land development projects may prove to be justified.

Summarizing, there appear to be several types of government interventions which cannot be abandoned, are beneficial in terms of welfare, or which in the long run affect comparative advantage itself. Together, these constitute the baseline for our analysis. National policies may adversely affect other countries through world markets. In the absence of a world authority which constrains national policies, this is unavoidable.

Also, to say that governments should not intervene, leaving economic regulation to market forces, is to suggest an objective which is not feasible. We have to live in a world where the choice is not between having intervention or not, but where limits may be recommended on the kinds of interventions which countries may apply. And even then, one can expect to be faced with large gray areas which cannot easily be classified in terms of their acceptability.

Objectives and Instruments

Nothing has been said so far about why national governments want to intervene in agriculture and the supply of food. Probably the most common purpose is to maintain a reasonable degree of self-sufficiency for those products which are staples. Behind this objective is the fear of overdependence on suppliers from abroad, particularly if they are few. Self-sufficiency arguments have historically played an important role and still do. The agricultural policies of the EC and Japan contain elements of self-sufficiency, and it is at the heart of policies in most developing countries.

In the course of development, the role of agriculture in terms of its share in output, exports, and employment tends to decline. Income elasticities of food demand decline once a major part of the population is well fed and there is a continuous risk of oversupplying food markets, leading to relative price declines and slow growth of real incomes generated by the agricultural sector. If migration out of agriculture does not compensate for slow overall growth of agricultural income, then incomes may fall further and further behind those in nonagricultural pursuits on a per capita or a per household basis. Governments may then want to intervene to improve the relative income position of farmers.

These two objectives -- self-sufficiency and farm incomes -- are the dominant motivating forces behind agricultural policies. Self-sufficiency objectives are common worldwide, but income policies are mainly found in the industrial countries which can afford their costs. There are also two sets of instruments used, prices of agricultural products and inputs, and nonprice measures. Within each set, there are further options.

A third possible objective is different -- the eradication of hunger. The links between agricultural growth and the demand for food are complex, and the objectives of promoting agriculture and eradicating hunger may even be inconsistent (Parikh and Tims, 1986). The interests of food producers and food consumers may lead to competing demands on the government's scarce resources and to opposite views on price policies. A majority of the poor are landless, and it is unlikely that they will be absorbed in agricultural activities that would provide them with the purchasing power to adequately feed themselves and their families. Nonagricultural employment is in the long run their only hope to escape from poverty. Investments to generate that employment compete for resources with the agricultural sector, as do subsidized food distribution schemes which are intended to relieve the worst effects of poverty. Reliance of the poor on market supplies of food gives them a strong interest in low food prices, whereas farmers producing a marketable surplus will have an opposite interest.

Meeting the food needs of the poor is no doubt an objective of many governments, but not one that is easily reconciled with objectives of food self-sufficiency in market terms, or with farm income objectives.

Policy-Induced Problem Areas

Two characteristics of policy making in the areas of food and agriculture bedevil the global scene. One is that agricultural and food policies are made independently by nations, primarily for domestic objectives. There are no international treaty obligations or codes of conduct that restrict national policies. There is an extensive network of international agreements which limit the use of some major trade policy instruments, vested primarily in the GATT (General Agreement on Tariffs and Trade). But agricultural products have remained outside its reach, having been explicitly excluded at the time the agreement was drafted. Only recently, in the Uruguay round of trade negotiations, has there been willingness -- reluctantly no doubt, by some -- to include agricultural products in these negotiations.

The second problem concerns the instruments used to obtain national policy objectives. A country pursuing self-sufficiency in a basic staple may do so in a variety of ways: increasing the price of the desired product, subsidizing some major inputs, or even providing free land development to farmers. Tax exemptions, cheap credit, and free extension services are equally usable means. But the effects on the balance of payments and on the country's trade relations may be quite different, in turn affecting other countries differently through world markets.

Different policies may achieve the same results in terms of self-sufficiency for the commodity in question, but may do so at different levels of demand, supply, and price. As a consequence, purchasing power of consumers is affected differently, and other markets of goods and services must find a different equilibrium. It is to be expected that the composition of external trade is also affected, with different compositions of both imports and exports. As a consequence, friction arises between countries, which question the acceptability of each other's policies. Many countries reject such complaints about their policies.

At the same time the formulation of national agricultural and food policies has become more complex. The days when it could be assumed that promotion of agricultural production would directly lead to a better food situation for most people are far behind us. The Asian countries in particular are approaching a state of self-sufficiency in market terms, with small alternating imports or exports. Increasing production further, beyond domestic market demand, would push these countries into volatile export markets if they are able to overcome infrastructural and quality constraints. If they can, domestic food prices will decline, maybe even more than is necessary to become competitive in world markets. This lower cost of food will no doubt benefit poor consumers, in particular the rapidly growing category of urban dwellers and rural landless households. But production will continue to increase when production costs of staple foods can be reduced simultaneously through new technology and through rural investments promoting its adoption.

Problems of balance

These choices between staying on the net-import side of self-sufficiency or pushing on to become a permanent net exporter — even if quantities exported remain small — are very hard to make. The implications for food supplies to the poor and for wage costs of nonagricultural activities suggest pushing into a net-export situation. If farmers' choices for their production patterns are limited, the effects of lower prices to them may not be so large that the country will again lapse into net imports. This may be the case, for example, with irrigated rice in South and East Asia.

If farmers can more easily move to other crops, much will depend on the policies that the country adopts for those, making sure that prices are set for all agricultural products in ways that ensure that surpluses can be exported, or at least that domestic production can compete with imports. Balancing the interests of both large and small producers and of consumers (including the poor), along with the need to save or earn foreign exchange within the limited resources of governments, has become a difficult act for almost all developing country governments.

These issues of general economic policy which arise as a corollary of agricultural and nutritional concerns are no longer the only ones. Economic issues are made even more complex, and decisions harder to make, because of a growing awareness of the ecological constraints of agricultural development. Loss of soil fertility, the dangers of unlimited river diversions for irrigation, and the risks associated with the use of chemicals in agriculture are examples. Health problems associated with some of these practices can no longer be omitted from discussions concerning agricultural development.

And finally, returning to the start of this discussion, there are increasing international frictions and tensions in the areas of agricultural growth and trade which cannot be ignored by national governments. In a world that is becoming increasingly interdependent, countries can no longer unilaterally exclude their policies from the international agenda. The potential costs of maintaining that stance are becoming too high. This adds an element of international political concern to the formulation of national policies, as their impact on other countries through world markets may bring repercussions that can wipe out the advantage of the policy measure itself.

All of these factors lead to a renewed assessment of existing national policies, both in terms of their internal and external effects. Policy changes require assessments, and a large part of the hesitation to discuss and negotiate can be attributed to the feeling that changes lead to new uncertainties. What happens when countries no longer create artificial barriers between their domestic prices and world market prices? Or if they abolish input subsidies? A major reason for this uncertainty is the large distance between the actual policies adopted by national governments compared to what would seem economically justified. Adjusting policies to the point where they become more economically rational is a very big step that is unavoidably resisted by interest groups which have grown accustomed to the benefits of government intervention.

Rent-seeking is a natural pursuit for all who try to cajole their governments to maintain or increase their rent income derived from government policies. Agriculturists, traders, consumers, and government officials themselves are all, to various degrees, making efforts to extract from their governments the commitment to protect their real incomes. Economic theory suggests, however, that this not only tends to lead to a less equitable distribution of income, but also to a smaller size of the total cake. Moving towards economically more appropriate policies will be hampered by the beneficiaries of the existing interventions, at best making the process slow, and at its worst, even impossible. Food riots when staple food prices are brought closer to world market prices, or spilling food in the main streets by farmers objecting to price reductions, indicate that these issues cannot be expected to be easily solved at the negotiating table.

Agricultural and Food Policies: Intended and Unintended Effects

Policies that are centered on domestic objectives are intended to sort specific effects in the domestic economy, particularly for the group(s) of people to which the policy is explicitly addressed. The effects these policies have on other countries are usually not taken into account and if at all referred to, are not considered relevant because there are few internationally agreed-upon rules that restrict domestic policy options. In addition, there are other domestic effects which are not foreseen at the time when the particular policy is enacted, or at least not expected to be important. In fact these may only become visible over time.

Some of these indirect, longer-term, and often unintended effects will briefly be reviewed here, notably in relation to policies geared to self-sufficiency and/or to relative improvement of farm incomes. Domestic effects are discussed first, followed by an overview of international consequences.

Welfare losses through biased price policies

When a country sets domestic prices independently of the world market, it loses because the allocation of scarce resources is shifted away from their most efficient use. Many countries striving for a self-sufficient supply of staple foods have offered farmers relatively favorable returns when compared to other crops. In many developing countries these price relationships between crops were created by governments which at the same time kept the overall level of producer prices low compared to world prices. This is most obvious in the case of overvalued exchange rates. It reflects an element of food policy — keeping food prices low for consumers — but is also defended as a way to extract resources from the agricultural sector to finance nonagricultural investments.

These policies have caused significant changes in cropping patterns, particularly in developing countries. Availability of new technologies for some food crops has added to these shifts when land development and infrastructure permitted, and the new technologies added to the relative attractiveness of a crop in terms of net revenue. It is not at all certain that higher prices for agricultural producers in general would have brought about a much higher rate of overall agricultural growth, because most of the evidence suggests low overall supply responses to higher relative prices of agricultural versus nonagricultural products. Supply constraints are to a much larger extent associated with the characteristics of subsistence farming – the physical conditions, and the lack of infrastructure for marketing and processing.

Shifts of agricultural production patterns were the result of price policies by themselves, even more so when associated with new technologies. Particularly in Asia, where the investments in land development have in the past been substantial, price policies did lead to self-sufficiency in market terms for major food grains, i.e., in terms of meeting domestic market demand from mostly domestic supplies. It should be remembered, however, that major sectors of the populations of those countries still remain hungry because they lack the purchasing power to buy adequate food on the market. Agricultural development by itself cannot resolve that problem.

The focus of policies on major staple foods can also be expressed as a relative – but in fact sometimes absolute – neglect of other crops and livestock products. For example, the major crops in Pakistan that were the focus of policy attention substantially increased their share of total cropped acreage and agricultural value added. The country has remained an important exporter of cotton and rice, and has become self-sufficient in wheat, but it faces rapidly increasing foreign exchange expenditures on vegetable oils, sugar, milk, and meat. It may well be that the prevailing natural conditions in Pakistan would be better suited to crops other than wheat, which it could import more cheaply than the commodities for which the country is increasing its import dependence.

The inefficiency of cropping patterns measured at world market prices is one consequence of these price policies. Another consequence, particularly for Africa, is more concerned with the relative prices of all agricultural products which are kept low compared to nonagricultural products. To a large extent this situation is a result of strong protection for the industrial sector, which places agriculture in a disadvantageous position. It may not have significantly slowed agricultural growth, but it has reduced the efficiency of domestic industries, employment growth, and real consumption below feasible levels.

Self-sufficency and income policy goals

A policy of self-sufficiency in basic staple foods, when pursued by price policies that drive wedges between domestic and international prices, affects welfare, employment, and consumption. The policy objective is not necessarily to be rejected for those reasons because there are other arguments – particularly political – which may weigh more heavily in the decision-making process. But one should be clear about their economic costs.

What applies to self-sufficiency policies applies also to farm income policies when those are pursued through managed prices. The price wedges driven at their borders by the EC, Japan, other European countries, and for some products by the US and Canada, have their economic costs — as distinct from budgetary outlays — because they increase the internal costs of agricultural products and make the rest of the economy less competitive.

Income objectives can be achieved by a variety of policy alternatives. Where price supports to farmers are favored, particularly in the EC, one needs to raise the question whether the selected option is the most efficient. It appears that a large part of the costs supported by consumers paying higher prices and taxpayers supporting the EC budget do not reach the farmers, but rather finance large stocks and subsidies to consumers outside the EC through export subsidies. Direct income supplements with a limited intervention in agricultural markets may be a more efficient alternative. Apart from actual cost saving, this may also lead to less distortion of markets and price formation, and thus a smaller overall loss of welfare.

All of these policies, which intervene in markets and separate domestic from world prices, change production patterns when the natural and physical infrastructure does not permit accelerated overall growth. If the level of land development, infrastructure, and market access do not impose constraints, higher prices will accelerate agricultural growth. Taking the EC as an example, high producer prices, which for many years seemed to be permanent, provided the incentive to invest in agriculture. Banks had few doubts about the return of credit extended to farmers because there was little market risk. The availability of financing, together with a strong demand for advanced technology, provided a powerful incentive to agricultural research. Agricultural production and productivity now exhibit strong upward trends, supported by widespread development and adoption of new technologies. These trends now seem to be invulnerable to lower prices, at least in terms of the impact of price reductions in the first few years after policies have shifted.

The focus on self-sufficiency for staple foods and the income support policies which tend to concentrate on major farm products, have significantly shifted the global balance of supply and demand. Asian countries would probably still be large importers of food grains, the EC would not have become a major net exporter of several commodities, Canada might not be self-sufficient in dairy products, nor the US in sugar, if these selective supports had not applied. As a consequence, world supplies are larger than demand. World market prices are low, compelling some countries to subsidize their exports to avoid large stocks. In the end, world markets balance, although at prices which are not profitable for major traditional exporters. It is more appropriate to describe the situation of the past 10 to 15 years with the term *distorted*, rather than unbalanced, markets.

Africa and USSR – Another story

It is doubtful whether the rising import dependence in Africa should be attributed to inappropriate price policies. Low relative prices to farmers have obviously discouraged farmer production for the market, but it is unclear whether a better price policy would have made Africa less import dependent. One reason is that the absence of even remotely adequate marketing infrastructure and transport systems makes market prices almost totally irrelevant for a large segment of the farmers. Second, a major bottleneck is scarce labor, given the level of agricultural technology. Improvements in that technology require closer linkages to the national economy and are hampered by the same lack of infrastructure.

But even if the infrastructure were improved, technology delivered to the farmer, and surplus production sold at a price that gave a reasonable return to the farmer, there would still be doubt whether food production would be significantly affected. Small subsistence farmers are mainly women and the risks of farming are synonymous with the risks of life. When those are high because land is not developed – such as unleveled land without any water control – the willingness to change practices may be impaired. Price policies should not be neglected in Africa, but import dependence may continue to grow notwithstanding sound price policies.

Similar arguments apply to the Soviet Union, which has been a major food importer for the last 15 years. The prices paid to farmers may need to be raised (and more of the collective income may need to be distributed to members on the basis of actual contributions), but major bottlenecks will remain in handling, processing, and transporting agricultural products. Many years of high investments in these supporting facilities will be needed, together with major programs of water control, to reduce import dependence.

Without the food demand from the Soviet Union and the rising imports of Africa, world prices of major agricultural commodities would be lower than they are now. Surpluses created at one end of the scale by inappropriate price policies are to some extent compensated by inadequate investment policies in the rural areas in other parts of the world. This tends to highlight the importance of a view of agricultural development which embraces both the price/input/technology side and the composition of investment activity.

In the end, inappropriate combinations of investment and price policies distort market factors. African agriculture is labor intensive with low returns; agriculture in the Soviet Union is similar. It makes labor scarce and too expensive in the nonagricultural sectors and draws capital away from agriculture. In the EC, the competitiveness of the nonagricultural sectors is reduced by high food prices as an element of wage costs, drawing more investment resources towards agriculture than world prices warrant.

Potential Remedies and Cures

There are two reasons why the present agriculture and food policies around the world will change: the disappointments experienced with the policies of the past, and the international frictions they have brought in their wake. The current phase is therefore one of change. Depending on the objectives, it may also be a phase of promise.

One should, however, note that the changes that are coming about in agricultural and food policies, both nationally and possibly also through international agreements, are only to a limited extent concerned with the promotion of a more rational economic use of resources. Many countries want to reduce the budgetary costs of farm and food policies and avoid surpluses that cause international tension and bring possible retaliation. The instruments used for these purposes do not necessarily also promote a more economic allocation of resources. The EC's inclination to use quantitative production controls, rather than to reduce price supports, is such a case.

The proposals the US has submitted to GATT on agricultural trade are at another extreme. They aim to completely dismantle all agricultural support measures and thus move strongly towards free trade. Other countries have submitted less far-reaching proposals which will move in the same direction. In the developing countries, steps are also being taken in that direction as part of structural adjustments. It is therefore reasonable to assume that in the next 5 to 10 years there will be a gradual change of policy towards agricultural free trade.

Several studies have estimated the effects of free trade on agriculture (Parikh et al., 1988). Although the methods differ a good deal and the results must be interpreted with care, some of the results are strikingly similar. One is that world market prices for a number of agricultural products will establish themselves at a higher level, primarily because subsidized exports will disappear. Another finding suggests that countries that reduce their agricultural protection reap a benefit in terms of higher GDP growth, with gains in the nonagricultural sector overcompensating for the loss in the agricultural sector. This is found particularly in the industrial countries, whereas developing countries show a more mixed pattern of net gains and losses.

The fact that the effects of moves towards free trade seem to produce a net economic benefit should not be taken at face value. The more important point may be that different groups are affected differently within countries. In the EC, farmers stand to lose, but consumers and taxpayers may gain. In exporting developing countries, farmers will mostly gain and consumers lose; in importing developing countries, the same will apply if governments permit domestic prices to rise to world price levels. In many developing countries, there will be rural gains and urban losses, but in the industrial world, the opposite will occur.

These internal differences are of considerable political and social importance. They may become major barriers to change as categories of people will insist on their right to be supported by the government, whether they are farmers in the rich countries or urban consumers in the developing ones. Governments will in many instances not be able to extricate themselves from the conflicts associated with policy changes without committing themselves to some kind of compensation. How this is to be done, who will be compensated, to what extent, for how long, and where the financing originates are the issues that arise in internal discussions, once international pressure makes a move towards free trade likely.

One particular feature of possible moves toward free trade needs to be emphasized. All available evidence from existing studies suggests that the effect of these moves on world hunger is negligible. This is particularly true when the industrial countries liberalize, but the developing countries do not do so. But even if the latter join in this policy move, the positive effects on the reduction of hunger remain small. This should not come as a surprise, as most of the poor depend for their food supplies on markets; higher world market prices reduce their real purchasing power. Slightly positive effects may be felt in some of the poorest countries, because a large segment of the poor are still agricultural tenants or laborers; they would participate in the benefits from higher prices for agricultural products.

Future Consumption and Production Trends

There is one basic feature of the future food balance which deserves some emphasis – the dominance of consumer demand. Because food is a basic need of a growing world population, consumption projections are barely affected by alternative price and income assumptions. This is also true in many of the more advanced developing countries with low incidences of hunger and malnutrition, but to a lesser extent in the poorest countries of South Asia and sub-Saharan Africa, which harbor the vast majority of hungry people. But even in those countries, a large segment of the population with adequate food supplies exhibits a limited food-consumption response to price and income changes. The overall response in those countries therefore depends on the distribution of the benefits of economic growth, with a relatively more limited response in the case of more inequitable distribution of income growth.

Therefore, the dominant factor behind growth in consumption is the increasing world population. Different assumptions about income increases and price developments entail only limited changes in food consumption. One of the major features of consumption patterns in the long run is the changing composition of the diet. The demand for food grains for direct human consumption grows more slowly, while the demand for dairy products and, to a lesser extent, for other livestock products grows more rapidly. The demand for food grains for animal feed rises somewhat because of increased consumption of livestock products. There is a clear shift in consumption patterns, particularly in developing countries, toward more expensive foods. This shift is pronounced because a fairly large number of countries, or large population segments in these countries, are passing through a phase of income growth in the years ahead where the demand for the traditional staple foods is fully met, and increased income fuels a shift to more expensive food rather than to the direct consumption of larger quantities of traditional foods.

In a scenario which assumes no change in present agriculture and food policies, developing countries continue to favor the production of food grains and export crops. Their output of livestock products does not rise sufficiently to meet domestic demand, and they become increasingly dependent on imports, particularly of dairy products. At the same time, food grain imports continue to increase, but at a lower rate compared to past years. Most growth of food grain imports takes place in the more advanced developing countries, to a large extent to meet feed demand.

Continuation of present policies implies that the major potential suppliers of livestock products — the industrial countries — set prices independently from world market prices. Rapidly rising demand on world markets therefore does not meet with responsive supplies, and as a consequence livestock products become considerably more expensive. At the same time, slow growth in the demand for grains gradually reduces world market prices as worldwide production continues to be promoted. With gradual removal of protectionist policies, the world market picture changes significantly, notwithstanding little change on the consumption side of the balance. Production changes, measured both in terms of domestic production patterns and their geographic composition, are slightly larger. Trade, which is a small proportion of agricultural production and a residual between consumption and production, shows substantial changes both in volume, geographic patterns, and prices.

When trade is liberalized, the most significant change occurs in food grain prices, which rise significantly in world markets as a number of suppliers have to withdraw from the world market or become net importers when border protection is removed.

This is particularly true for wheat in the EC, rice in Japan, and coarse grains in a number of smaller producing countries which are currently either exporters or importers. For wheat and coarse grains, the volume of world trade is reduced compared to the baseline scenario, reflected particularly in lower imports (for feed use) by middle-income developing countries. World trade in rice expands substantially as Japan becomes a net importer, mainly from Thailand and from small Latin American and Asian exporters.

At the same time, the removal of border protection leads to further world price increases for livestock products, and a substantial expansion of international trade. For dairy products, there is a major reduction of EC exports and the US becomes a major importer, as is Japan. Canada and New Zealand are major beneficiaries, but a number of Latin American, African, and Mediterranean countries also become significant exporters. Many developing countries expand their meat production, reducing imports or moving into exports.

All of this suggests the importance in the years ahead of focusing on the livestock sectors in developing countries, and on the feed inputs for that sector.

Research Priorities

The foregoing does not suggest a straightforward research agenda, but indicates a number of issues for discussion. For example, it would probably be incorrect to conclude that rice and wheat research should be de-emphasized, because appropriate varieties have yet to be developed and adopted in a number of countries. But particularly in Africa, further work should recognize that economically attractive land development is of prime importance as a precondition for techn ological progress. In a number of cases it may be preferable to adopt this more comprehensive view of agricultural development opportunities, rather than to focus research largely on adaptation to existing physical circumstances.

Changing consumption patterns justify a focus on crops which are important for the livestock sector, including not only feed grains and crops that provide nutritious by-products for animal feeds, but also specific fodder crops which can be fitted into prevailing cropping patterns. In many countries, the major constraint to livestock production is not the efficiency with which animals convert feed into livestock products (thus focussing on the genetic properties of animal breeds) but rather that existing herds are severely undernourished; research must emphasize enlarging and improving the animal diet as a means of discouraging the growth of herd sizes. These are complex issues which require improved markets for livestock products, veterinary services combined with insurance facilities for livestock holders, in addition to more and better feeding. But research on feeding and fodder crops has a major contribution to make.

Oilseeds deserve more attention, not only because of expected changes in human consumption, but also to improve animal diets. In many developing countries production has stagnated and imports are increasing, reflecting the neglect of these crops by past agricultural policies. Vegetable oil imports deny the livestock sector a nutritious by-product. Developing countries which produce valuable feeds like molasses and oil cakes export these products rather than using them in the domestic livestock sector. This is directly related to EC price policies which put a premium on substitutes for grain because of high internal grain prices in the EC. In many cases it would be appropriate to levy an export tax on these commodities to lower their domestic price and thus to make them more attractive to the domestic livestock sector.

It will also be useful to focus the discussion of research priorities more on production systems, rather than on individual crops, because the activities of most smallholders and their choices are hampered by only marginally improved land, and by a poor rural infrastructure. Focussing on one or two crops is clearly not the best way to improve their opportunities. Farming systems research leads to a better perception of the constraints they face, but ultimately research must encompass land development opportunities in order to visualize ways to change production patterns and to bring about development. Technological change may falter unless accompanied by measures to improve the prevailing physical conditions through appropriate investment programs.

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Research Policy Implications of Global Food Surpluses for Developing Countries[1]

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The North American climate during this past summer has, at least temporarily, changed the premises on which this session of the seminar was based. The worst drought in some 50 years has driven up the prices of important commodities at a rapid rate, despite large stocks of these commodities in the United States and the European Economic Community. Perhaps more importantly, it has alerted both policymakers and researchers that predictions of a greenhouse effect from the accumulation of several minor constituents in the atmosphere, including some from agriculture, may be valid and might materialize more rapidly than expected.

There is an important positive side to these developments, however. They have reminded us once again just how fragile the base of our global food supplies really is. They may also help sustain the political will around the world to support agricultural research programs, even though the justification may in part be for the wrong reasons.

A second or third consecutive year of drought in North America, such as occurred in the 1930s, the last time there was such a severe drought, would make this session completely academic. But let's be optimistic and assume the drought does not continue, and that in another year or two we will once again be facing the same conditions which we were facing prior to this current year. That will help us to focus on the important issues the situation of surplus supplies created.

My paper is divided into four parts. In the first part I want to focus on the contribution that new production technology — the output of research by biological and physical scientists — makes to economic growth. I find it necessary to discuss this issue because of the all-too-frequent tendency to lose sight of the basic issues. The second part will deal with the sources of recent imbalances in food supplies, while in the third part I will discuss my concerns about the existing capacity for agricultural research in the developing countries. In the fourth part, the research priorities implied by the recent imbalances will be discussed.

Production Technology as the Source of Economic Growth

Correctly understanding the way in which new production technology serves as a source of economic growth is a useful basis for assessing the research policy implications of global food surpluses. Unfortunately, there is an all-too-frequent tendency to assess the contribution of agricultural research from only the producer perspective. Agricultural research is perceived as a means to improve the welfare of farmers, without considering some of its broader contributions. Critics of existing research systems and programs stress the importance of focusing on small farmers and marginal areas, and emphasize using agricultural research as the means to change the distribution of income within agriculture more generally.

These perspectives fail to recognize the fundamental ways in which new production technology contributes to economic growth. They also implicitly assume that new production technology is an efficient and/or cost-effective means of changing the distribution of income among producers — an assumption which is questionable at best, and based on little empirical evidence or research.

Conceptualizing new production technology as a source of new income streams is a sounder basis for understanding the benefits of technical change in agriculture, and of understanding its contributions to economic growth. When viewing the process from this perspective, the contributions of the new technology are sought more broadly in the economy. Fully identifying the contributions provides a sounder basis for research policy.

What we know about the process of technological change is that the ultimate beneficiary tends to be the consumer, not the producer. This is especially true of technological progress in the production of staple food commodities, where the price elasticity of demand tends to be low — often significantly less than / 1/ (the absolute value of 1). With such a low demand elasticity, competition will tend to lower the commodity price more than the increase in productivity, other things being equal. Many producers will be worse off as a consequence, even though the rise in productivity is essential to raise the per capita incomes of those farmers who eventually remain in agriculture.

The consumers, of course, benefit from the lower prices. For given levels of nominal income, consumers will realize increases in real income for each decline in real food prices. Moreover, consumers with low incomes will realize proportionately larger increases in real income than do consumers with higher incomes because they tend to spend a larger share of their income on food than do upper income groups.

It is important to emphasize two points at this juncture. First, the power of agricultural research and new production technology as a source of economic growth is specifically because its benefits are so widely shared in the economy, especially when developed for widely consumed commodities. (This is also why the rate of return to such investments tends to be so high.) The corollary is that the importance of agriculture and of agricultural research has little to do with the share of the labor force employed in agriculture. Its importance is because everybody consumes food, and in low-income countries the majority of the citizens spend most of their income on food.

The second point worth emphasizing is that new production technology tends to have a progressive effect on income distribution for the economy as a whole, even though it may worsen the distribution of income within agriculture itself. Agricultural research and new production technology are seldom credited with this important contribution. If they were, policymakers might be more favorably disposed to invest in agricultural research.

In not all cases, of course, are the consumers the major direct beneficiaries of new production technology. In some cases, such as the case of beef, the price elasticity of demand may be larger than /−1/ and thus producers will receive the major share of the benefits. More important, if the commodity for which new production technology is being made available is a tradeable — either exported or imported — and the country is relatively unimportant in international markets, then producers will reap economic benefits since costs will fall and the price will remain relatively unchanged. Ultimately, the owners of land and supplies in relatively inelastic supply receive the benefits.

Even in this case, however, there are significant benefits to the general economy. The new technology should make the country more competitive in international markets and thus increase foreign exchange earnings. This should finance a higher rate of economic growth, thus increasing employment and providing expanded income streams.

Three points are important in concluding this section. First, when it is recognized that consumers are the primary beneficiaries of larger food supplies, and that reductions in food prices provide widely based increases in real incomes, the problem of surpluses is put in a somewhat more positive perspective. Second, an important issue will be to deal with the severe adjustment problems associated with low commodity prices. And third, the challenge to policymakers is to increase economic growth by the generalized increases in real incomes generated by the decline in food prices.

Causes of the Recent Imbalances in Food Supplies

Articles in the United States press over the last two to three years imply that commodity price declines during 1985-1987 were due to production burgeoning out of control in the developing countries, primarily because of new production technology used by producers in those countries. The supporting evidence for these articles is typically data from some experimental plots which show how much yields increase with the use of some improved variety, with little understanding of the difficulties in transferring increased yields on experimental plots to increased yields on farmers' fields.

The argument that global food surpluses can be attributed to burgeoning supplies in developing countries is not supported by the evidence. The last time I looked at the data, which was about a year ago, agricultural production in the developing countries as a whole was almost exactly on the same trend line it was on during the 1970s. Ironically, that trend line gave rise to Malthusian alarums, with pleas for Americans to eat one less hamburger a day so as to release grain for developing countries (never mind that hamburger in general is not made from grain-fed beef!), and suggestions that we might need to engage in triage, letting some people die in order that others could live.

There has been a modest increase in food availability in developing countries since the mid-1970s. But that increase has been due to an equally modest decline in population growth rates, not to supplies burgeoning out of control.

Thus, the causes of surpluses have to be sought elsewhere than in supply shifts in developing countries. Basically, the problem of low commodity prices in the mid-1980s had three causes. The first was the very weak demand during that period, created by very sluggish worldwide economic growth. With a few exceptions, the United States was the only country coming out of the deep recession of 1982-1983 with any kind of sustained economic growth. Developing countries in particular, in marked contrast to the "boomy" years of the 1970s, have been locked into slow growth patterns due to the international debt crisis. Many of these countries had to chop off their imports in order to save foreign exchange for debt servicing.

A second factor contributing to the problem of weak demand has been policy reforms which developing countries have made to deal with their debt problems. Many of these countries have devalued their currencies as part of reform packages. These realignments in exchange rates reduce the demand for imports and shift a larger share of domestic production to export markets. This is in sharp contrast to the prevalence of overvalued currencies in the 1970s, which served as import subsidies.

The third, and probably most important factor contributing to the slump in international commodity prices in the mid-1980s was the export subsidy war between the United States and the European Community. This export subsidy war, motivated by the high prices paid to producers in the USA and EC, and the subsequent accumulation of large stocks, helped drive prices to all-time low levels.

Obviously, consumers benefit from such an export subsidy war. But produce. fer (as do landless workers), whether the country is a net exporter or a net importer. The income streams of producers were reduced, as were their asset values, and producers and landless workers were forced to bear large adjustment costs. For countries that were net exporters, the dumping leads to losses in national welfare.

To conclude, the main causes of the collapse in agricultural commodity prices in the 1980s were the export subsidy war between the USA and EC, and weak demand associated with sluggish economic growth worldwide. The export subsidy war has been rooted in global distortions in international trade, and the unwillingness of the USA and EC to implement adjustment policies and programs for their own producers.

The Existing Capacity for Agricultural Research in Developing Countries

Two aspects of the existing capacity for agricultural research in developing countries are of concern. The first is that the growth rates of agricultural output needed in developing countries are outside the historical experience of the presently developed countries. The second is that the existing capacity for research in developing countries is far short of what it should be. Of particular concern is the lack of capacity in the developing countries to provide the trained manpower needed to staff even existing research systems.

Consider the first issue the needed rates of growth in agricultural output. As noted above, the global economy came through a period of very sluggish growth in the 1980s. However, that sluggish growth is not likely to continue. In fact, my own perspective is that globally we are about to experience a period of unprecedented economic expansion in which inadequate food supplies may be the main constraint to a more rapid general economic expansion.

Some aspects of our present situation should be examined. First, per capita incomes for large parts of the world have actually declined significantly since about 1980. Recovery from such declines is often rapid. Second, many countries have been through painful adjustments as they changed the configuration of their economy to be more consistent with external realities. Once that adjustment process is over, their economic expansion will be more rapid. Finally, there is a great deal of unutilized and underutilized technology available for adoption, not so much for agriculture, but for use in other sectors of the economy. The adoption of this technology can fuel rather rapid rates of economic growth.

However, one does not have to appeal to unprecedented growth rates to show that the expected growth in demand for agricultural output can easily lie outside the historical experience of the developed countries. Consider a few parameters of the present situation. In most developing countries, population is growing by 2% to 3% per year, with a significant number having growth rates above 3% per year. Given low levels of per capita income, the income elasticity of demand for agricultural commodities in the aggregate for such countries tends to be much higher than in industrialized countries, perhaps on the order of 0.6. Finally, increases in per capita income in late-arriving developing countries of 3% to 5% per year are quite feasible, since late-arrivers can adopt techniques and technologies from other countries, especially for the nonfarm sector.

Now consider the implications of these parameters for increases in the demand for agricultural output. A 2% population growth rate, combined with a modest 3% growth rate in per capita income, gives a growth in demand for agricultural output on the order of 3.8% per year. A more rapid rate of population growth of 3%, combined with a more rapid, but still quite feasible increase in per capita incomes on the order of 5% per year, results in a growth in demand for agricultural output on the order of 6% per year.

Hence, recovery of the global economy can easily lead to increases in demand for agricultural output in the range of 3.5% to 6.0% per year.

Now consider the supply side of the equation. The historical record shows that very few countries, either developed or developing, have been able to increase agricultural output on the order of 4% to 5% per year, except when extensive new areas were brought into production. Brazil is an example of a country that has been able to sustain a growth rate in agricultural output on the order of 5% per year. But this was done by bringing 1 million ha of new land into production each year, while at the same time significantly increasing productivity.

Bringing such additional land into production is not without a price, especially when the costs of the necessary infrastructure are taken into account. More important, not many countries still have such land available. In country after country, population pressure is pushing cultivation onto lands that are at best marginally suited for agricultural production.

These data all point to the need for continued and growing investments in agricultural research, despite extended periods of low commodity prices. The risk in our present situation is not that we will commit too many resources to agricultural research, but rather that we will significantly underinvest in this important source of economic growth, with the result that the agricultural sector will be a brake on global economic expansion in the years ahead.

International trade provides still another dimension to this problem. Given the emergence of a global food and agriculture system, producers in most countries now produce for a global market, not just for domestic consumers. The increased specialization in production that this system makes possible not only contributes to more ample markets, it is also an important source of more rapid economic growth.

Brazil's experience in this area is important, while at the same time emphasizing the importance of rapid economic growth and rising demand for agricultural output. Brazil's agricultural output grew at a rate of 5% per year during 1970-1981. This was one of the highest growth rates in agricultural output in the world during this period -- generally a period of rapid economic growth among the developing countries. However, during this same period, Brazil's imports of US farm products alone grew at a rate of 15% per year in quantum terms, and at a rate of 25% per year in value terms (Vocke, 1987). This illustrates what a strong factor international trade can be as a component of the demand against the agricultural resources of individual countries.

Now, consider the other side of the coin -- the capacity to produce the new technology needed for agricultural modernization and productivity growth. The available data on this issue are contained in publications by Boyce and Evenson (1975) and Judd et al. (1983, 1986). ISNAR has more recent estimates, but these data are still being refined.

These data show that expenditures on agricultural research and scientific staff significantly increased between 1959 and 1980. However, the resources committed for this purpose in developing countries are significantly less than those committed in the industrialized countries.

This is not an issue of developing countries not being able to afford agricultural research. Such research is not a consumption good; it is an investment. Moreover, it is an investment which the available research indicates has very high social rates of return (Ruttan, 1984). These results suggest that as of 1980 the developed countries had not increased their investments to the point that they drove down the rate of return at the margin. There is thus no evidence that developing countries should reduce their expenditures on and commitment to agricultural research as a consequence of surplus commodities.

There is another way of viewing this issue. Vernon Ruttan often makes the point that, given the location specificity of agricultural research, a comprehensive global agricultural research system would have an agricultural research station in each ecological zone of the world. Obviously, most developing countries are far from attaining that goal. As a source of general economic growth, and as an aide to sustaining a globally efficient agricultural research system, there thus seems to be little reason to reduce efforts to build such a system because of the recent appearance of commodity surpluses.

The real issue is to understand why developing countries continue to significantly underinvest in this potentially important source of economic growth. An important issue may be their general economic policies which discriminate so severely against agriculture by means of distortionary trade and exchange rate policies. These policies shift the domestic terms of trade severely against agriculture, and thus lower the social rate of return to investments in agricultural research. In effect, agricultural prices are kept low by decree; thus, reducing the returns from investments in agriculture and in agricultural research.

The export subsidy war between the USA and EC may also be having an especially pernicious effect in this regard. Dumping by these two political entities, which has contributed to low prices in international commodity markets, also lowers the rate of return to investments in agricultural research by developing countries. If the USA and EC were willing to sustain this dumping, then it would be socially optimal for developing countries to invest in agricultural research at low levels. In effect, they would be receiving income transfers from the EC and USA and could thus allocate their scarce development resources to other uses.

However, it is most unlikely that the EC and USA would be willing to make such a commitment, or that in practice their export subsidies will continue very far into the future. Developing countries, as well as the international donor community should thus view the surplus problem as a short-term phenomenon and sustain their efforts to develop the capacity for agricultural research in the developing world.

This brings us to the final issue on the supply side of agricultural research: the grossly inadequate capacity for the training of agricultural researchers in developing countries. As Judd et al. (1986) note, this lack of training capacity is a barrier to the expansion of agricultural research capacity. They note that only India, the Philippines, Brazil, Mexico, and a few other countries have doctoral programs in the agricultural sciences, but their capacity is quite limited. Because of this limited capacity to train scientists at advanced levels, potential researchers are trained abroad, thereby significantly increasing the costs of expanding research systems.

Unfortunately, two factors make this situation even bleaker than this description implies. First, the nascent PhD programs in developing countries have hardly been brought up to international standards (Schuh, *in press*), and thus they have not been capable of sustaining their own capacity. Second, the severe economic problems many developing countries faced in the 1980s made it difficult to sustain the capacity of existing systems. Hence, the capacity for training PhDs in countries such as Brazil and the Philippines is probably lower today than it was in the early 1980s.

Current agricultural surpluses may be a reason to shift scarce development resources to develop stronger graduate training programs. The objective would be to take advantage of cheap supplies at the present time, but at the same time to build the capacity for the future when an installed research capacity will have a higher social payoff. Given that the development of stronger graduate training programs implicitly involves the support of research, there should be minimal loss of momentum in existing research efforts from this shift of resources.

Implications for Research Priorities

My diagnosis of the causes of recent agricultural surpluses has important implications for agricultural research priorities. It does not, however, imply any reduction in the support for biological and physical research to develop new production technologies for agriculture. If anything, my diagnosis suggests that the social rate of return to such investments may be even higher in the future, especially if we have the global economic expansion I expect, with its strong increase in demand for agricultural output.

If there should be a shift in the resources allocated to the biological and physical sciences, it should be to increase support for graduate training programs in developing countries, both at the master's and PhD levels. This shift needs to be made in any case, if developing countries are to lower the cost of expanding their agricultural research systems, and to make them self-sustaining. It is interesting that this important issue receives so little attention in contemporary discussions of sustainability.

A second important research priority is the need to allocate more resources to agricultural economics, rural sociology, anthropology, and political science. Current surplus problems are the result of distorted domestic, trade, and exchange rate policies in both developed and developing countries. These same policies lower the social rate of return to investments in agricultural research and thus contribute to the persistent underinvestment in agricultural research.

There are currently gross distortions in the world's use of agricultural resources. Developed countries in general subsidize their producers by paying them prices that are significantly above border price levels. Developing countries discriminate against their producers by maintaining prices significantly below border price levels. The result is that a significant share of global agricultural output is produced in the wrong places: far too much is produced in the high-cost developed countries, and far too little in the low-cost developing countries (World Bank, 1986).

This configuration of policies reduces the efficiency with which the world's agricultural resources are used. The loss in efficiency significantly lowers global output and global income, while a more efficient allocation of the world's agricultural output would lead to significant increases in total agricultural output and global income.

The payoff to investments in social science research which would lead to a more efficient allocation of the world's agricultural resources would obviously be quite high. Yet today agricultural research still tends to be seen as research by only biological and physical scientists, not by social scientists.

Ironically, these distortionary policies undoubtedly lead to persistent underinvestment in agricultural research per se. Moreover, the existence of these distortions makes it difficult to obtain a socially optimal global allocation of the world's agricultural research resources (i.e., to rates which fully exploit the potential of agricultural research to contribute to economic growth), thus further sacrificing economic growth globally.

The needed social science research should focus on a number of important issues. First, we need to better understand how current policy distortions affect the allocation of the world's agricultural resources, and the costs of these policies in terms of sacrificed output and income. Second, who pays the costs of these policies and who receives the benefits, both within national economies and on a global scale, needs further investigation. Third, a great deal more research needs to be directed to understanding why governments do what they do. Such knowledge is needed if there is to be any hope to rationalize policies.

Understanding the effects of economic policies on the rate of return to investments in agricultural research is also important. Such knowledge may make it possible to better understand the present global allocation of agricultural research resources, and should also contribute to a more globally efficient allocation of the world's agricultural research resources, as well as helping to increase the investment in agricultural research to more socially optimal levels.

Still a third set of issues has to do with devising ways to better understand the agricultural adjustment problems in both the developed and developing countries (Schuh, 1986). In the former, failure to address adjustment problems has led to their highly protectionist agricultural policies. For the latter, dumping by the USA and EC imposes large adjustment costs. In general, devising more efficient ways of dealing with adjustment problems will increase the social rate of return to investments in agricultural research, since it reduces the adjustment costs associated with agricultural research per se.

Finally, an important payoff from investments in social science research is the design of new institutional arrangements, either as more rational economic policies, or as institutions which influence the allocation of resources or the distribution of income. As Hayami and Ruttan (1985) note, these new institutional arrangements constitute the social technology which is equivalent to the production technology of the biological and physical scientists. Although social scientists have not given as much attention to evaluating the social rate of return to investments in their own research as they have to evaluating the social rate of return to investments in production research, the limited evidence we do have suggests that the rates of return can be quite high.

Conclusion

The new production technology which agricultural research makes possible is a powerful source of income streams and, hence, economic growth. To the extent that the problem of surplus production is transitory, there is little reason to reduce the commitment to agricultural research. An important issue, however, is that these surpluses may be reducing the expected rate of return to investments in agricultural research by developing countries. This points to the importance of greater investments in social science research in order to improve global agricultural policies, and to address the adjustment problems associated with policy rationalization. Improved and more efficient adjustment policies and programs should increase the social rate of return to investments in biological and physical research.

Notes

1. For a companion piece to this paper, which discusses some of the same issues from a different perspective, see Schuh (1987).

2. That is, on the order of −0.4 or −0.2, which means that quantity demanded responds very little to price changes.

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Session I
Summary

Food Surpluses and Their Research Policy Implications for Developing Countries

Introduction

The phenomenon of food surpluses in the developed, industrialized countries amidst scarcity in many developing countries provided an excellent focal point for the two plenary speakers. They elaborated on the interrelationships between broad economic and social policies, agricultural sector policy, and agricultural research policy, and the interdependency among countries across the globe — the main theme of the workshop.

Food surpluses as policy-induced phenomena

Tims sought to clarify the origins of food surpluses — market phenomena induced by individual policies undertaken by sovereign governments. He said that governments govern and manage through policies, and since "any policy itself has impacts on markets and the real variables of the economy, . . . there can not exist an economy free from policy-induced distortions."

Consequently, the ideal liberal world of markets free of policy interventions can not be a practical goal. From Tim's point of view the current discussions concerning liberalization, deregulation, and prioritization are therefore simply second- best alternatives to current third-best solutions.

Both speakers recognized overproduction in the developed, industrialized countries as the principal cause of the recent food imbalances. In addition, Schuh cited two other major factors:

- a very weak demand during the period created by very sluggish economic growth worldwide;

- policy reforms undertaken by many developing countries to deal with their mounting debt problems, which included devaluation of national currencies as part of their economic reform packages. Devaluation effectively reduced demand for imports and shifted a larger share of domestic production to exports.

Schuh reiterated the significance of new agricultural production technology as a source of economic growth, but said that there is a tendency to assess the contributions of agricultural research from the producer side alone. He challenged the assumption that new production technology is an efficient or cost-effective means of distributing income among producers. He stressed that in the process of technological change, the ultimate beneficiary tends to be the consumer, not the producer, and therefore the contributions of new technology should be sought more widely in the economy to provide a sounder basis for research policy.

Major global trends in food and agriculture

Using food surpluses as a starting point, and building on the fine contributions of the plenary speakers, the working groups discussed global trends in food and agriculture which have far-reaching consequences for developing countries. Of the many observations contributed by the participants, three appeared to be dominant:

- an expected reduction of surpluses in the developed countries;

- rapidly increasing demand for agricultural products and changing consumption patterns;

- increased difficulty in obtaining the kind of agricultural growth achieved in many countries in Asia and Latin America during the last two decades.

Expected reduction of food surpluses in the developed countries. The background and consequences of global food supply imbalances and distortions were clearly discussed by both plenary speakers. The imbalance originates with government policies, usually to protect rural incomes or to achieve a certain degree of food security. They are sustained by farmer interests and other domestic beneficiaries of those policies. However, both shared the view that food surpluses from the industrialized countries could be expected to diminish in the future.

Tims foresaw "in the next 5-10 years a gradual change towards free trade in agriculture." For his part, Shuh considered it "most unlikely that in practice their [EC and US] export subsidies will continue very far into the future. Thus, the developing countries, as well as the international donor community, should view the surplus problem as a short-term phenomenon."

The working groups tended to agree with the plenary speakers' conclusions, but expressed reservations on how soon and to what extent the industrialized countries will act on the problem.

One view expressed was that "the necessary adjustments are extremely tough political decisions which will take time before they can be accepted within those countries. In any event, there will very likely be a long transition period before they can be fully implemented." Yet another view was that "even though we may assume that surpluses are going to be reduced in the course of time, they will never disappear entirely, and therefore global surpluses may always mask regional differences."

The inclusion of agricultural products in the GATT negotiations for the first time was also noted, but there were serious doubts expressed about the immediate outcome. One working group raised the issue of how the developing countries could participate more effectively in the trade policy dialogue and underlined the importance of policy research as a factor.

Rapidly increasing demand for agricultural products and changing consumption patterns. Both plenary speakers cited increasing food demand and changing consumption patterns as major developments that developing countries must face. Schuh pointed out that "population increase and growing per capita income will be the driving forces of food demand increase in developing countries in the coming years." Moreover he stressed that the estimates of population and income growth that govern existing forecasts are too conservative.

Assuming that the global economy continues to recover from the recession of 1982-83, and taking into account a population growth rate of 2-3% per year, Schuh postulated the demand for agricultural products in the developing countries to grow at the rate of 3.5-6.0% per year, a growth rate which he emphasized is outside the historical experience of most countries, developed or developing.

Between population increase and price and income changes, Tims argued that population growth is the more dominant factor behind consumption growth. However, income increases and price changes do induce changes in food consumption patterns. Tims recognized that in the longer term, changing composition of diets will tend to become more significant as large segments of the population in a fairly large number of developing countries pass through a stage of income growth when the demand for traditional staple foods is fully met. At this point income increases shift consumption towards more expensive food rather than to the direct consumption of larger quantities of traditional food items.

One working group felt that Schuh's accelerated growth of demand may be an overestimate, but conceded that even with more pessimistic assumptions on per capita income growth, many developing countries will find it difficult to meet the challenge.

In assessing the relative balance between population and income as determinants of consumption growth, the working groups recognized regional and national differences. Population growth has begun to moderate in many parts of Latin America and Asia, but not in many parts of Africa. The demand for livestock products is expected to increase more rapidly in many parts of Asia as incomes rise.

Increasing difficulty in achieving high agricultural growth. Schuh emphasized that the forthcoming demand for agricultural production may in fact be beyond the historical experience of most developing countries. The challenge becomes more daunting when one realizes that there is virtually no new land that can be cultivated, and that the easy gains from fertile irrigated environments have in part already been exploited by the Green Revolution during the last two decades. As the yield potential from the major cereals levels off, one working group expressed uncertainty about where the new sources of growth potential will come from.

The implications of these observations for most if not all the developing countries are indeed enormous. The sense of urgency is all the more acute for many parts of Africa with their inherently infertile soils, unfavorable moisture regimes, and lack of physical and social infrastructure.

Needed Development Policies

All the working groups addressed the implications for development policy of the food surpluses in the developed countries and their possible reduction in the medium term. As Tims argued, and participants agreed, freer trade policies in agriculture will tend to lead to the disappearance of subsidized exports, and the establishment of higher market prices for such commodities. In this scenario, the developed countries will generally gain with a higher GDP growth by reducing their agricultural protection, while the developing countries will show a more mixed pattern of net gains and losses. Moreover, groups will be affected differently within countries. In the EC, farmers stand to lose, but consumers and taxpayers may gain. In exporting developing countries, farmers will mostly gain and consumers lose; in importing developing countries the same will apply if governments will permit domestic prices to rise to world price levels. In many developing countries there will be rural gains and urban losses, but in the industrial countries the opposite will be the case.

Each of the developing countries, therefore, will have to adopt broad economic policies and agricultural development strategies appropriate to their respective situations. Since agricultural trade is now part of the GATT negotiations, there is some hope that the more obvious distortions may at last be addressed.

The expected reduction of food surpluses in the developed countries is potentially very important to certain developing countries and to certain sectors within those countries in the immediate and medium term. But it may be less far-reaching than the more fundamental problems of the rapidly increasing quantity and sophistication of consumption demands in the developing countries as a whole, and the increasing difficulty of reaching the high growth rates necessary to meet those demands.

The working group discussions were not designed to produce an in-depth analysis of development policy issues. However they did identify key development issues, which may be grouped into five themes:

- agricultural policy distortions;
- population policy;
- food security policy;
- rural infrastructure policy;
- development of national research capacity.

Agricultural policy distortions

Recognizing that policy distortions exist, the working groups spent some time on a number of topics relevant to many developing countries. These policies at times have unintended or unrecognized adverse consequences. One topic was food aid and its short- and longer-term consequences for the recipient countries. While food aid brings immediate welfare to target beneficiaries, and to governments which monetize the foreign aid, it can have an unwanted long-term impact on the agriculture of the recipient country.

For some countries the pressing issue is understanding and anticipating the impact and adjustment costs associated with externally imposed liberalization policies. One working group struggled with the notion of what constitutes "useful protectionism."

No specific conclusions emerged from these clusters of topics, except a recognition of the need to develop the capacity to identify and assess the impact of different development policies on a country's agriculture.

Population policy

The working groups were almost unanimous in recognizing the primacy of population growth in driving consumption growth, and consequently, the deteriorating ability of many developing countries to meet ever-rising consumption demands. These concerns were expressed in the working group reports:

- It is essential, especially in Africa, for population growth to become an explicit policy issue. Only then can effective measures be developed.

- We feel obliged to come out strongly with a statement calling on governments to increase efforts that will moderate and stabilize population growth.

- Stress on natural resources is caused both by human and bovine pressure, trends that are seen both in Africa and Latin America. Development policy actions require measures to control population growth through incentives and disincentives. These kinds of efforts must be accompanied by clear land-use and development policies.

Food security policy

One working group focused on the universal concern of governments for food security. They stressed that while it is a rational and legitimate objective, the institutionalization of policies aimed at food security can lead to distortions in domestic markets, support inefficient production, and adversely affect income distribution.

The working group cited the danger of temporary policy measures designed to meet short-term food security interests becoming permanent distortions of the system, especially where "food self-sufficiency" rather than "food security" becomes the inadvertent target.

As alternatives, the working groups suggested that food security policy may incorporate such measures as early-warning systems, introduction of buffer stocks, and integration of markets between countries. However these need to be studied further to assess their suitability to different countries.

Physical infrastructure and support services

A major bottleneck for agricultural development in many developing countries is the often inadequate physical infrastructure and support services for agriculture. The working groups advocated more government investments and attention to rural infrastructures such as irrigation, farm-to-market roads, electricity, and post-harvest facilities, as well as the promotion of rural credit, extension, input supply systems, farmer organizations, and other rural institutions. Having called for this investment, one working group emphasized the need to consider cost recovery in the planning and management of rural infrastructure.

Development of agricultural research capacity

As Schuh points out in his paper, "the new production technology which agricultural research makes possible is a powerful source of income streams and hence of economic growth." Schuh however warns that "the existing capacity for research in the developing countries is far short of what it should be."

Continuing, Schuh contends that "the real issue is trying to understand why the developing countries continue to significantly underinvest in this potentially important source of economic growth. An important issue here may well be the general economic policies in the developing countries which discriminate severely against agriculture by means of distortionary trade and exchange rate policies. These policies shift the domestic terms of trade severely against agriculture and thus lower the social rate of return to investments in agricultural research."

The working groups elaborated on this theme in the discussions and concluded that the developing countries, with the assistance of the donor country, should "redouble the efforts to strengthen the indigenous capacity of developing countries to adapt and generate improved agricultural technologies."

Institutional strengthening efforts however must vary among regions, reflecting their recent histories and current needs. Thus for Africa, it is "institutional development" in the specific sense of nationalizing research institutions, building up human resources, and construction of physical structures, and where they have been recently put into place, making them work.

For many countries in Latin America, one working group used the term "re-institutionalization" – the rebuilding of national systems that have undergone periods of neglect and decline.

For Asia, the call is for meeting "second-generation problems," continuing support and stimuli to national systems that are losing dynamism after a period of real successes, and which now need to cope with challenges and opportunities of increasing complexity.

Last, the international community will have to look into the research needs of very small countries in many parts of Africa, in the Pacific and Caribbean, and a few countries in Latin America, Asia, and the Middle East which have very limited resources to establish and maintain national agricultural research institutions.

Needed Agricultural Research Policies

The strengthening of indigenous agricultural research capacity in developing countries as a vital dimension of overall development policy provides the backdrop to specific agricultural research policies. The working group discussions focused broadly on these specific themes:

- research priorities;
- improved management of NARS;
- enhanced capacity for rural social sciences;
- development of graduate programs in the agricultural sciences;
- improved linkages between research and extension and the farmers.

Research priorities

The projected rapidly increasing demand for agricultural products in developing countries suggests a broadly based effort to further increase country investments in agriculture itself, and in the research support the sector requires. In a sense, this means "more of everything." However in assessing what the new priorities might be, the plenary discussions and working groups were able to highlight a few.

Export crops. If developed countries embark on freer trade in agriculture, their surpluses in commodities such as wheat, maize, rice, soybeans, sugar, and fruits would decline, and thereby open opportunities for developing countries to exploit the export market for these products. The developing countries that can produce these crops must intensify their research efforts on these potential export crops for both quantity and quality.

Livestock. As large population segments in many developing countries attain higher income levels, consumption patterns will shift to more expensive goods, such as dairy and other livestock products. Production research for livestock, including field grains and forage crops, will need to be intensified. This trend is manifesting itself now in many parts of Asia.

Vegetable oil crops. There is a need to focus more attention on vegetable oils. International and national efforts during the past two decades have concentrated on cereals and other staples. In addition to their relevance for direct human consumption and nutrition, oil cakes as a by-product from vegetable oil crops are fed to livestock.

Less favorable environments. Increasingly, many developing countries must look into the potential of nonirrigated and marginal lands for increased production. Since much of the previous development effort has concentrated on irrigated and more fertile environments, there are fewer proven production technologies for less favorable environments.

Farming systems research. There is increasing recognition for the need for more farming systems-type research to adapt technologies to the economic and social circumstances of resource-poor farmers who, after all, constitute the majority of producers. Their lack of production resources is often confounded with the problem of less favorable environments, which makes the research challenge all the more complex.

Tims, however, cautioned the workshop against an overly narrow research focus based largely on the adaptation to existing physical circumstances. Particularly in Africa, Tims contended that "further work should take into account possibilities of land development which appear economically attractive and which can go hand in hand with technological progress. Farming systems research leads to a better perception of the constraints small farmers face. Focus on one or two crops is clearly not the best way to improve their opportunities. But in the end it is research that promises to affect the entire production pattern that will bring about a measure of development. It may well be that this will not succeed unless accompanied by measures to improve the prevailing physical conditions through appropriate investment programs."

Improved management of national agricultural research systems

The need for improved management of NARS was consistently brought out in the working group discussions. These concerns were raised again in the succeeding sessions, but at this stage those that were highlighted included the need to

- link research with the national planning and resource-allocation process;
- improve strategy- and priority-setting mechanisms;
- link research with specific (e.g., area) development programs;
- train and upgrade management skills;
- improve conditions of service for researchers.

Enhanced capacity for the rural social sciences

Strengthening research in the rural social sciences was considered vital by the workshop participants. There was clear support in the group discussions for Schuh's proposal that more research resources be allocated to the rural social sciences. He argued that there is a need for an increased understanding of how current policies distort the allocation of the world's agricultural resources, and the costs of these policies in terms of sacrificed output and income. More knowledge is needed on who pays the costs of these policies and who receives the benefits, both within national economies and on a global scale. Essentially what is needed is a better understanding of why governments do what they do, if there is to be any hope to change policies to a more rational mode.

In supporting these views, the working groups pointed out the need to develop both macro and micro economic and social research capacity. There are not enough policy analysts in the NARS, according to one view.

Examples of needed social science research, several of which were cited in the preceding sections, included the following:

- short- and long-term effects of food aid, including the impact on domestic food production and consumption, as well as on the reduction of the level of support for domestic agricultural research;
- the economic and political costs and benefits of food self-sufficiency versus broad food security (including cash and export crops);
- the employment and sustainability dimensions of population issues;
- the impact of policies designed to earn foreign exchange, protect infant sectors, and protect privileged political interests.

Improved linkages between research and extension

The concern of the participants for better research and extension linkages was echoed repeatedly during all the deliberations of the workshop. If the developing countries are to meet the challenge of fast agricultural growth to meet rising populations and changing consumption demands, their NARS simply must increase the pace and effectiveness of the generation and transfer of appropriate technologies to researchers, extension agents, and farmers-producers.

Development of graduate programs in the agricultural sciences

Schuh underscored the grossly inadequate capacity for training agricultural researchers in the developing countries. Because of this limited capacity to train scientists at high levels, potential researchers have to be sent abroad for advanced training, thereby significantly increasing the costs of expanding research systems.

The call for more training and human resource development was reinforced by all the working groups. In a multi-pronged effort to improve training capacities and opportunities for the developing countries, four ideas were detailed:

- There is a need in many African countries for well-trained manpower at both research and technical levels.

- The potential of the IARCs for training should be further exploited.

- University-to-university collaboration among developing countries and with developed countries should be further developed.

- There is a need to explore opportunities for more formal degree training at the regional level.

Training and human resource issues were taken up prominently in the final discussion of this session, in particular the brain-drain phenomenon. The complexity of the problem was underlined when it was pointed out that the loss from the developing countries of highly trained manpower does not apply only to agricultural scientists, but also to doctors, engineers, teachers, and other professionals, and even unskilled workers. The conditions of service within the NARS have to be improved dramatically if they are to hold on to their most valuable resource, but action on a sectoral basis is problematic.

The loss of researchers from public institutions to the private sector within the country was also dramatized, particularly for the younger NARS which have as yet very few highly trained staff. Although their departure does not represent a total loss to the country, nevertheless their movement presents serious management problems.

An opposite perspective was expressed on behalf of the older, bigger, and more established NARS in the countries that have the domestic capacity to produce graduate scientists. There, transfers to the private sector were viewed as healthy because they

- help improve technological competence in the private sector and facilitate technology transfer;

- increase the market for talent and thereby help recruit bright, young students to careers in the agricultural sciences;

- provide upward mobility for younger scientists in the public sector;

- serve as alumni who provide formal and informal links between public research institutions and the private sector.

Session II

Linking Growth in Agriculture with Growth in the Rest of the Economy: Research Policy Implications

Linkages between Agriculture and the Overall Economy

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The linkages between the agricultural and nonagricultural sectors of an economy are many and varied. They operate through intersectoral movement of production factors, such as labor and capital, as well as goods and services. With increased agricultural productivity and reduced labor requirements per unit of output, labor tends to move out of agriculture, especially when the population is increasing. In most developing countries, the percentage of the population engaged in agriculture, which is often 60% to 70%, exceeds the percentage of gross domestic output that is contributed by agriculture, usually 30% to 40%. Labor productivity is low in agriculture. However, in many developing countries in recent years, the proportion of the population engaged in agriculture has tended to decline, not so much in response to increased agricultural productivity, but rather as a result of the pressure from increased poverty and unemployment in agriculture.

Also, the growth in the agricultural sector generates surpluses which contribute to expanding investment in the nonagricultural sector. Either financial institutions mobilize and transfer savings for investment in the nonagricultural sector, or the public sector mobilizes agricultural surpluses by fiscal and commercial policies to invest in the nonagricultural sector.

Agriculture as a Source of Savings and Foreign Exchange

Because agriculture is important as a source of national income in many developing countries, attempts to mobilize substantial savings for national investment need to rely heavily on the agricultural sector: the lower the level of per capita income, the higher the percentage of national income originating from agriculture. The relative importance of agriculture as a source of employment and income is seen in Table 1. Even if agriculture is not an important source of overall national income or employment, it may still be a very significant source of income in a particular region within a country.

Table 1. Agriculture's share of GDP, employment and exports, selected years, 1964-84

	Share of agriculture (percent) in					
	GDP		Employment		Exports[1]	
Country group[2]	1964-66	1982-84	1965	1980	1964-66	1982-84
Low-income countries	42.8	36.3	76.0	72.0	58.6	32.8
Africa	46.9	41.3	84.0	78.0	70.7	68.4
Asia	42.5	35.7	74.0	71.0	54.0	25.9
Middle-income oil exporters	21.8	14.8	62.0	50.0	40.8	13.6
Middle-income oil importers (excluding major exporters or manufacturers)	25.2	18.0	63.0	53.0	54.2	44.8
Middle-income oil exporters (major exporters or manufacturers)	19.3	12.1	50.0	36.0	56.9	20.2
Developing countries	30.2	19.9	66.9	63.2	52.3	22.0
Industrial countries	5.1	3.1	13.7	7.1	21.4	14.1

SOURCE: World Bank (1986).

1. Includes reexports.
2. Data for developing countries are based on a sample of 90 countries.

Frequently in a depressed or underdeveloped region of a middle-income or even a high-income country, the majority of the population derive their income from agriculture, and agricultural progress and its stimulating impact on the nonagricultural activities within the region are crucial for regional development. Substantial population migration is seldom a feasible way to solve poverty and unemployment, especially in the short and medium term, even though with improved infrastructure and education over time, expanding opportunities in the industrial sector would provide income and employment to the migrating population.

In most developing countries, investment resources are mobilized from the agricultural sector by means of commercial, exchange rate, and fiscal policies. In many countries, taxes on agricultural exports are often the major source of government revenue, while an overvalued foreign exchange rate depresses the return on many agricultural exports in domestic currency below world market prices. At the same time, the domestic industries have access to agricultural inputs that are priced below the world market. Also, quantitative restrictions on industrial imports protect manufacturing industries. This generates the high profits in the import-substituting domestic industries, and provides resources for investment in the industrial sector. The heavily protected domestic industries squeeze agriculture in two ways. First, the prices of industrial inputs used by agriculture and of the manufactured goods consumed by farmers rise above world prices and shift the terms of trade against agriculture. Second, higher profits from investment in the industrial sector divert private savings from the agricultural sector to the industrial sector.

In general, the producers of export crops are paid less than world prices (Table 2). In some cases, domestic prices are as much as 30% below world prices, as estimated at the official rate of exchange. In recent years, the price of food crops has been raised above the world price in several countries to encourage domestic food production. However, in many cases, domestic prices of both food and export crops are lower than world prices, if the latter are estimated in terms of scarcity price or equilibrium rate of foreign exchange. With an overvalued exchange rate, the domestic price equivalent of world prices of internationally traded commodities is depressed below what farmers would have received at an appropriate exchange rate.

The mobilization of resources away from the agricultural sector is inevitable in the early stages of development. The critical factor is whether the resources mobilized in the agricultural sector are invested within that sector to an extent which is commensurate with its needs and the opportunities for profitable investment. Also relevant are the mechanisms through which resources are mobilized from agriculture for investment within and outside agriculture. To extract resources by turning trade terms against agriculture through overvalued exchange rates and quantitative import restrictions is not a very efficient measure. Furthermore, it acts as a disincentive and depresses agricultural growth — the very source of surplus in the early stages of development. Direct taxation of agricultural income and land is a more efficient way to mobilize resources. However, administrative and institutional constraints in many developing countries make them rely heavily on taxes from commodity exports and imports. At the same time, this provides an opportunity for the government to channel resources back to agriculture through public expenditures.

Public expenditure devoted to agriculture in many countries is no more than 11% to 15%, which falls far short of what is required in terms of agriculture's importance as a source of income and employment. The agricultural sector provides 60% to 70% of total employment. Both private and public investment in agriculture must be raised

Table 2. Direct and total nominal protection rates, 1975-79 and 1980-84 (in percent)

Country	Product[1]		1975-79		1980-84	
			Direct	Total	Direct	Total
Argentina	Wheat	(X)	−25.1	−41.4	−12.7	−49.4
Brazil	Wheat	(F)	35.2	3.4	−6.5	−20.2
	Cotton	(X)	13.4	−18.5	2.6	−11.1
Chile	Wheat	(F)	10.8	33.2	9.3	2.0
	Grapes	(X)	1.0	23.4	0.0	−7.3
Colombia	Wheat	(F)	4.8	−19.7	8.9	−25.3
	Coffee	(X)	−7.0	−31.5	−4.9	−39.1
Dominican Republic	Rice	(F)	19.6	2.1	25.7	6.3
	Coffee	(X)	−14.9	−32.4	−32.3	−51.6
Egypt	Wheat	(F)	−18.6	−36.8	−21.0	−34.9
	Cotton	(X)	−36.3	−54.4	[illegible]	−35.7
Ghana	Rice	(F)	79.2	13.2	118.4	29.4
	Cocoa	(X)	25.6	−40.4	34.0	−55.0
Ivory Coast	Rice	(F)	7.6	−24.9	15.5	−10.0
	Coffee	(X)	−31.5	−64.1	−25.2	−50.8
Korea	Rice	(F)	90.8	73.1	86.2	73.9
Malaysia	Rice	(F)	37.8	33.5	68.0	58.4
	Rubber	(X)	−25.2	−29.5	−18.3	−27.8
Morocco	Wheat	(F)	−7.4	−19.0	−0.1	−8.0
Pakistan	Wheat	(F)	−12.5	−60.8	−20.6	−55.2
	Cotton	(X)	−12.3	−60.6	−7.3	−41.8
Philippines	Rice	(F)	1.2	−26.0	0.1	−28.2
	Copra	(X)	−10.7	−37.9	−26.0	−54.3
Portugal	Wheat	(F)	14.5	9.2	25.9	13.1
	Tomatoes	(X)	17.1	11.8	17.1	4.2
Sri Lanka	Rice	(F)	17.8	−16.8	10.6	−20.8
	Rubber	(X)	−28.5	−63.1	−31.3	−62.7
Thailand	Rice	(X)	27.7	−43.1	−14.9	−34.0
Turkey	Wheat	(F)	27.8	−12.5	−3.3	−38.6
	Tobacco	(X)	1.8	−38.4	−27.6	−62.9
Zambia	Corn	(F)	−12.8	54.3	−8.8	−65.9
	Cotton	(X)	−13.4	−55.0	−4.6	−61.7

SOURCE: Krueger et al. (*in press*).

1. *F* = food crops, *X* = export crops.

beyond current levels in most developing countries if agricultural growth and, consequently, overall growth are to be accelerated.

An important link between the agricultural and the nonagricultural sectors (which is closely related to agriculture as a source of savings) is that in many developing countries agriculture provides the majority of foreign exchange for essential imports. The relative contribution of agriculture to export earnings in developing countries is shown in Table 3. Agriculture's contribution to foreign exchange earnings is high even in countries where the percentage of national income derived from agriculture or the proportion of employment provided by agriculture is small, for example in Latin America. As the rate of development accelerates, demand for imported investment goods and intermediate inputs goes up rapidly. Under these circumstances, increasing agricultural exports remains a key source of foreign exchange. Agricultural exports provide the needed foreign exchange component — capital equipment and

Table 3. Agricultural exports from developing countries as a percentage of total exports, disaggregated by per capita income

	Per capita income[1]		
	Less than $400	$400–1600	More than $1600
Agricultural exports as a percentage of total exports	(Percentage of countries in income categories)		
More than 80	61.1	30.3	12.5
60–80	11.1	39.4	25.0
50–60	11.1	–	25.0
40–50	8.3	6.1	12.5
30–40	2.8	15.2	12.5
Less than 30	5.6	9.1	12.5

SOURCE: Based on UNCTAD (1981).

1. Not all columns total 100% because of rounding.

intermediate inputs -- to enable domestic savings to be fully utilized, and thus help remove foreign exchange constraints on domestic investment.

Consumption and Production Linkages

In addition, there are intersectoral linkages of two different types: consumption and production. The part of the income generated in the agricultural sector which is spent on nonagricultural goods and services provides the consumption linkage: the higher the level of per capita income in agriculture, the higher the percentage of total expenditures spent on nonfarm goods and services.

At the same time, the nonagricultural sector provides markets for food and agricultural raw materials. The forward production linkages are processing, marketing, distribution, and the further fabrication of agricultural goods for use in the nonagricultural sector. The trade and commerce sector in developing countries, especially in rural areas, is predominantly engaged in marketing and distributing agricultural commodities.

Nonagricultural inputs provide a backward production linkage because the agricultural sector uses fertilizer, pesticides, irrigation equipment, and other mechanical equipment to harvest, plow, weed, and transport agricultural commodities.

In countries where agriculture either constitutes a large percentage of national income or provides a major source of employment, the growth linkages generated by agricultural development are likely to be strong because the impact on the total economy through production and consumption linkages is also likely to be strong. Technical progress, which contributes to increased production and higher incomes in the agricultural sector, stimulates overall growth. The higher the rate of technological progress, the more widespread is the impact on large and small farmers, traditional and cash crops, and arid or irrigated land. This affects not only agricultural growth but also the rest of the economy.

The impact of technological progress on employment in agriculture depends on the growth rate and growth pattern in output; the latter is the composition of output and choice of techniques. Technological progress in the form of biological and chemical innovations is usually widely diffused with a time lag affecting both large and small farmers. Usually there are no economies of scale in such innovations, and therefore small farmers benefit from them, provided they have access to credit and to inputs that increase yields.

Mechanical innovations, however, tend to be labor saving. In many developing countries, mechanization has been encouraged by a public policy of keeping labor more expensive and capital cheap, resulting from either a high wage policy or a low interest rate policy, including an overvalued foreign exchange rate. Mechanization, however, does not necessarily have an overall negative impact on employment. The effects of direct negative employment through displacement of labor in some agricultural operations such as plowing or havesting may be compensated by the creation of additional employment through a higher cropping intensity, as well as in the production, maintenance, and repair of equipment. A larger aggregate output and a higher cropping intensity, such as multiple cropping due to mechanization, increases agricultural labor requirements. Thus, the type and nature of technological progress in agriculture is relevant to the magnitude and intensity of intersectoral linkages. A recent study, for example, indicates that in many Asian countries during the 1970s, a 10% increase in value added in agriculture led to a 3% to 4% increase in employment (Ahmed, 1988).

Technological Progress, Food Price, and Overall Economic Growth

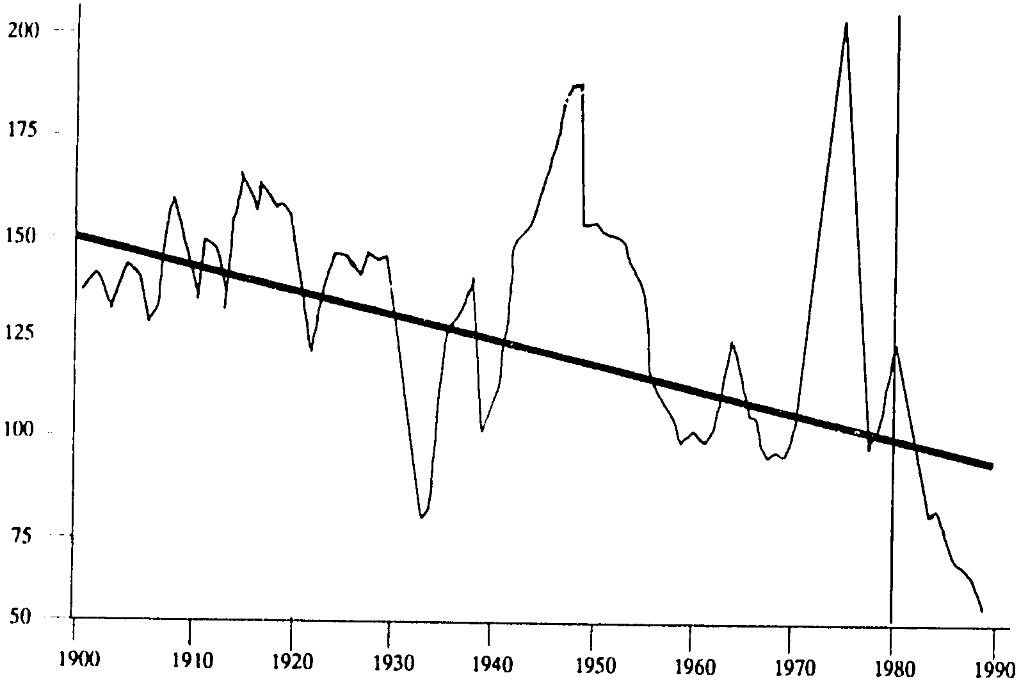
One important way in which agricultural progress affects overall economic growth is by reducing food prices. When demand for food is fueled by either increasing per capita income or population growth, cost-reducing technological progress reduces food prices and offsets any inflationary pressure in the economy.

In an open economy, domestic prices equal border prices plus tariffs. In a closed economy, where domestic prices are higher than world prices due to quantitative restrictions on imports, an increase in food production leads to a fall in domestic prices. With price elasticity of food demand in developing countries less than unity, a fall in food prices also reduces the gross income of food producers. But since a fall in the value of output is matched by a fall in unit costs, there is neither net loss nor excess profit in a competitive market. Where there are differences in efficiency or costs among individual products, more efficient farmers earn extra profits. Frequently, however, technological progress does not take place in a vacuum; at the same time, population and income growth lead to an expanded demand, which keeps food prices from falling to the full extent of their reduced costs. In many instances, the government intervenes through a price-support program to prevent a short-run decline in prices to the full extent of the reduced cost and to also prevent the corresponding fall in the income of food producers. However, to the extent that a country imports food and sells it domestically below the world market price, technological progress, which increases production at lower per unit costs, enables it to reduce food imports and distribute the benefits of cost reduction via lower prices and lower subsidies.

Technological progress does not uniformly extend to all food producers in all regions simultaneously. Those producers who do not enjoy the benefits of cost-reducing technological innovations will be confronted with a lower market price without having the simultaneous advantage of higher productivity and lower cost. They lose from technological progress in which they do not share. If the losers happen to be poor farmers with no secure access to new technology, and the gainers are a few large producers, then rural income inequality and poverty are aggravated. Therefore, the need for wide diffusion of technological progress to maximize its beneficial impact on the producers can hardly be overemphasized.

On an international level, when many countries enjoy the benefits of cost-reducing technological innovations, the world price is likely to fall, thus benefiting the food-importing countries. Historically, technological progress resulted in a downward trend in world cereal prices, which benefits both producers and consumers (Figure 1). As unit costs in the exporting countries fell, rising populations and per capita income in both exporting and importing countries partly offset the downward pressure on prices.

Figure 1: Long-Run Trend in Food Prices



Based on Anderson and Tyers (1987).

The impact of technological innovations on cost and price depends on the extent to which the marketable surpluses in a country increase in relation to demand. Only a portion of the increase in output is marketed. Medium-sized and large farmers have a higher ratio of marketable surplus in relation to output compared to smaller farmers. If an increase in output is concentrated among smaller farmers, they will consume most of it because of their low consumption levels and high demand elasticity. The downward pressure on market prices will be correspondingly less. On the other hand, if the largest part of the increase is concentrated on a few very large producers with large marketable surpluses, without any corresponding increase in income and demand from poorer farmers, then the downward pressure on prices is likely to be large. If the fall in prices exceeds the fall in costs, the income of the surplus-producing farmers would be adversely affected. Their incentive to continue increasing food production will suffer, unless there is an offsetting increase in demand by consumers.

Low food prices which follow cost-reducing innovations directly improve the real income of the poor, who are the net purchasers of food. Technological progress in food production, which enlarges the supply of the principal wage good – food – at a stable and low price, facilitates the adoption of an employment-based development strategy, especially in the nonfarm sector.

Furthermore, a fall in food prices improves the terms of trade of the industrial sector and lowers the real wage income in terms of the output of the nonfarm sector. This encourages labor-intensive industrialization, as well as a substitution of labor for capital, in the various processes and products in the nonfarm sector. However, the relative decline in the ratio of labor cost to capital cost in the nonfarm sector depends not only on the relative fall in the food prices, but also on a range of macro-economic policies which affect the relative prices of labor and capital.

The extent to which reduced food production costs and a relative fall in price improve the terms of trade in the industrial sector partly depends on the extent and the magnitude of marketing, distribution, and other transaction costs in the movement of food from rural producers to urban consumers. An increase in these costs would offset the impact of the relative decline in food prices.

Low wages, facilitated by cheap food, help expand labor-intensive exports, both agricultural and industrial. This is because relatively cheap food strengthens the comparative advantage of labor-intensive activities in the world market.

Agricultural growth stimulates expansion in the nonagricultural sector through consumption linkages, as well as forward and backward linkages in the production process. The consumption linkage is stronger than the production linkages. This is partly because in developing countries the ratio of purchased inputs in agriculture is low, and therefore the expansionary impact on the demand for agricultural inputs is limited. The magnitude of backward linkages increases rapidly as industrial structure becomes more complex and agriculture becomes more modernized and uses more purchased inputs. The relative importance of purchased inputs in gross agricultural output in various developing regions is shown in Table 4.

Table 4. Ratio of purchased inputs over gross outputs in selected developing countries

Country	*Ratio*	*Country*	*Ratio*
Argentina	26.98	Pakistan	12.22
Benin	8.65	Peru	18.07
Colombia	18.22	Philippines	28.00
Ecuador	17.23	Sri Lanka	17.17
India	24.43	Sudan	27.42
Indonesia	9.66	Tanzania	13.13
Korea	22.06	Thailand	6.38
Mexico	29.41	Turkey	32.48

SOURCE: FAO (1986).

In developing countries in general, the forward linkages from agriculture through processing and distributing agricultural output appear to be far larger than those from the originating side of inputs. The distribution of agricultural products undoubtedly generates the largest nonfarm production links for agriculture. If retailing agricultural produce is approximately proportional to its share in production and in total rural consumers' expenditures, then about 45% of rural retailing can be assumed to be forward distribution links with agriculture (World Bank, 1987: 97).

Consumption Linkages and Overall Growth

Increased purchases of nonfarm goods made with increased income in the agricultural sector potentially serve as an important stimulant to the nonfarm sector. The stimulus to growth is not confined necessarily to the rural nonfarm economy, but is also extended to the urban sector, depending on the extent to which the latter is integrated with the rural sector through transportation, communication, marketing, and distribution channels. Frequently the nonfarm goods and services on which increased income of rural agricultural households is spent are labor-intensive and produced in rural regions. The output of the nonfarm sector includes not only manufactured goods but also trade and other services. The role of trade and services in the rural areas as a source of employment and income has not been sufficiently emphasized. Much greater attention has been paid to manufacturing in areas such as handicrafts, cottage industries, and other small-scale rural industries. The rural services on which increased rural income is spent include, among other things, housing, education, health, transportation, and personal services (Hazell and Roeli, 1983).

As increased farm productivity raises farmer incomes, not only is a higher proportion of income spent on nonfarm goods and services, but also farm household income begins to diversify. At the level of marginal or very small farmers with land holdings too small to provide a minimum income, nonfarm employment is not only a supplementary source of income, but is often a high proportion of total income. As farm size increases, self-employment or employment of hired labor on the farmer's own land increases. At the same time, agricultural income as a proportion of total income of the farming household increases. However, as farm size increases beyond a certain level, or as the farmer's income exceeds a certain threshold, the share of nonagricultural income in total income rises again. As the very large farmers increase the productivity of their land and labor, they invest the savings generated by their higher income in nonagricultural activities and derive higher nonagricultural income.

Nonfarm income constitutes an important proportion of the total income of rural households in both India and Bangladesh (Tables 5 and 6). In villages in Bangladesh with well-developed infrastructures, and in India, the percentage of nonfarm income is highest among the smallest farmers or farmers in the lowest income groups — 44% in Bangladesh and 60% in India. With the increase in income among Indian farming families, the share of nonagricultural income in their total income first goes down and then goes up again for those in the highest income bracket (National Council of Applied Economic Research, 1980). In Bangladesh, the change takes place at a slower pace. Although the share of nonagricultural income is higher for the large farmers than for the medium-sized farmers, it is only by a small margin. This may be because large farmers in Bangladesh are not as large nor do they earn as high an income as those in India because the average level of poverty is higher in Bangladesh.

A study in Pakistan found that 40% to 50% of all marginal farmers had a nonagricultural occupation which substantially added to their incomes or significantly reduced their poverty. Furthermore, the productivity of marginal farmers increased because some members of farming households had nonagricultural income sources. Farmers invested their nonagricultural income in their farms. Thus, nonagricultural income was a source of capital for investment in the agricultural sector to purchase agricultural inputs, as well as for livestock development (Klennert, 1986).

Intersectoral consumption linkages depend partly upon income distribution in rural areas, especially the distribution of the incremental income that accrues in the

Table 5. Nonagricultural income as a percent of total income in rural households by technology and land ownership groups, Bangladesh, 1982

Land ownership group	Technology group[1]	
	Underdeveloped	Developed
Landless and marginal (0.5 ha)	61.9	43.9
Small (0.5-2.5 ha)	42.5	38.6
Medium (2.5-5.0 ha)	33.3	26.9
Large (5.0 ha)	24.1	30.0

SOURCE: Ahmed and Hossain (1988).
1. In developed villages high-yielding rice varieties have been sown on 80% of the total planted area.

Table 6. Composition of income by income ranges in rural India, 1975-76

Income range	Total income		
	Agriculture	Nonagriculture	Share of wage income
(Indian rupees)	(%)	(%)	(%)
<3,600	40.1	59.9	45.0
3,601 – 7,500	58.5	41.5	16.2
7,501 – 15,000	64.5	35.5	2.1
15,001 – 30,000	74.5	25.5	0.2
<30,000	40.5	59.5	–

SOURCE: National Council of Applied Economic Research (1980).

agricultural sector to different sizes of farming families. It is the medium-sized farmers who tend to nave the expenditure patterns that have a greater potential to stimulate demand for mainly labor-intensive, nonfood goods and services. They spend a higher proportion of their incremental income on nonfarm goods and services than do small and very small farmers. Because of their low income, the small farmers spend a much higher proportion of incremental income on food rather than on nonfood items. The direct stimulating effect of their consumption expenditures on the rest of the economy is therefore limited. However, the increased demand for food by poor farmers and landless laborers stimulates expanded food production, including production by medium-sized and large farmers. The increased production and income of these two groups in turn stimulates the demand for nonfarm goods.

In many instances, the medium-sized farmers are numerous and their absolute aggregate expenditure on nonfood items is often as great as, if not greater than, the aggregate expenditures of a larger number of small farmers. Expenditure of a higher percentage of an incremental income on nonfood items by the medium-sized farmers, starting with a large base, strongly stimulates nonfarm-sector employment and income.

In a number of studies in India, Malaysia, and Nigeria (Tables 7 through 10), it was found that if increased production is concentrated on very rich households, and not on the medium-sized and small farmers, e[illegible]enditure patterns are most likely to be skewed towards goods and services that are imported or are frequently capital intensive. In Malaysia, 63% to 66% of the incremental income of the medium-sized farmers, between the fourth and seventh decile in farm size, was spent on nonfarm goods and services in 1972-73. This went up to 74% for the highest income deciles. The percentage of locally produced nonf[illegible] goods in incremental aggregate expenditure was 38% to 40%, whereas the expenditure on imports from outside the region was about 26%. It is noteworthy that the average size of middle-income farmers in this context was quite small because the largest farm size in this study was no more than 15 ha to 20 ha.

Table 7. Food expenditure elasticities for low-income families

Country or region	Urban	Rural
Bangladesh	1.06	1.06
Brazil	0.83	0.83
Egypt	0.71	0.68
Indonesia	0.88	0.98
Malaysia		
Muda	–	0.88
Nigeria		
Funtua	–	0.89
Gusau	–	1.04
Sri Lanka	0.72	0.86
Sudan	0.74	0.84
Thailand	0.62	0.65

SOURCE: Alderman and Braun (1984).

Table 8. Rural household expenditure behavior in selected countries

	Average budget share					Marginal budget share				
	Gusau N. Nigeria	Rural Sierra Leone	Zaira Province N. Nigeria	Muda Malaysia	North Arcot S. India	Gusau N. Nigeria	Rural Sierra Leone	Zaira Province N. Nigeria	Muda Malaysia	North Arcot S. India
Commodity group										
Food, alcohol, and tobacco	80.7	73.7	56.5	66.7	78.2	76.1	67.9		37.7	63.0
Clothing and footwear	7.2	7.0	11.4	5.8	4.2	8.9	7.4		8.1	7.7
Consumer expendables	4.3	–	–	3.4	3.1	4.4			3.7	2.4
Housing	0.3	–	2.6	4.1	n.a.	0.4			12.4	n.a
Transport	1.9	2.2	1.5	1.8	2.8	2.7	3.0		3.1	3.4
Durables	1.1	–	2.1	0.6	1.4	.1	1.9		1.25	
Education and health	1.1	1.4	–	2.9	1.9	1.6	0.8		5.2	2.4
Services and social and religious obligations	3.3	4.3	13.5	13.1	9.1	4.4	8.1		22.7	19.3
Locational group										
Locally produced										
Foods	75.3	69.0	–	46.4	63.0	70.3	66.1		24.6	48.5
Nonfoods	8.4	8.8	–	18.1	17.4	11.3	12.3		36.9	30.8
Regional imports										
Foods	5.4	–	–	20.3	12.3	5.8	–		13.1	12.0
	22.2	21.6								
Nonfoods	10.9	–	–	15.3	7.4	12.6	–		25.4	8.6
Nontradables	24.7	–	–	23.5	17.6	32.0	–		40.6	24.1

Table 8. (continued)

	Expenditure elasticities				
	Gusau N. Nigeria	Rural Sierra Leone	Zaira Province N. Nigeria	Muda Malaysia	North Arcot S. India
Commodity group					
Food, alcohol, and tobacco		0.94	0.92	0.57	0.81
Clothing and footwear		1.24	1.06	1.39	1.85
Consumer expendables		1.02	–	1.09	0.77
Housing		1.40	–	3.02	n.a.
Transport	–	1.41	1.36	1.67	1.22
Durables		3.35	3.43	–	
Education and health		1.42	0.57	1.79	1.26
Services and social and religious obligations		1.33	1.88	1.73	2.12
Locational group					
Locally produced					
Foods	0.93	0.96	0.53	0.77	
Nonfoods		1.34	1.40	2.05	1.77
Regional imports					
Foods	1.07	–	0.65 0.97	0.98	
Nonfoods		1.16	–	1.66	1.17
Nontradables		1.30	0.87-1.62	1.73	1.37

Table 9. Marginal budget share by per capita expenditure decile in Muda, Malaysia, 1972-73 (percent)

Group	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
	Per capita expenditure decile[1]									
Commodity Group										
Food, alcohol, and tobacco	67.39	57.94	51.98	49.61	45.57	41.88	37.63	35.27	27.71	13.89
Cereals and cereal products	21.88	18.42	15.64	15.34	13.41	12.27	10.39	9.43	6.22	10.53
Fruits, vegetables, and nuts	9.85	8.75	8.30	8.02	7.60	6.98	6.79	6.49	5.94	4.42
Meat and fish	12.19	10.54	9.52	9.11	8.52	8.17	7.24	7.16	5.73	3.46
Eggs and dairy products	2.61	2.38	2.14	2.01	1.85	1.76	1.57	1.52	1.42	0.96
Clothing and footwear	7.92	8.20	8.33	8.38	8.14	8.07	7.94	7.70	7.87	7.44
Consumer expendables	4.58	4.25	4.10	4.13	3.95	3.79	3.67	3.59	3.52	3.10
Housing	2.51	5.50	7.88	7.64	10.06	10.55	12.35	13.76	15.47	20.29
Transport	2.33	2.53	2.77	2.82	2.84	2.96	3.09	3.01	3.26	3.58
Durables	−1.01	1.70	2.83	4.05	4.95	5.94	6.85	8.00	9.82	13.22
Education and health	2.22	3.16	3.31	4.12	4.05	4.89	5.17	5.45	6.53	7.71
Personal services and entertainment	1.65	1.99	2.33	2.12	2.39	2.40	2.36	2.39	2.63	2.89
Social obligations	12.41	14.73	16.45	17.12	18.06	19.53	20.94	20.82	23.18	27.89
Locational Group										
Food										
Home-produced	22.47	18.36	15.44	15.54	13.52	12.54	10.22	9.71	[illegible]	−1.17
Locally produced	21.40	19.47	18.11	16.99	16.05	15.07	14.29	13.55	12.75	9.88
Imported	23.53	20.11	18.43	17.08	16.00	14.27	13.12	12.02	9.62	5.18
Nonfood										
Locally produced	17.87	23.50	27.70	28.74	32.06	34.21	37.36	38.91	43.06	52.79
Imported	14.74	18.56	20.31	21.64	22.37	23.90	25.01	25.82	29.23	33.32
Nontradables	23.72	28.64	32.42	33.35	36.30	38.12	41.07	42.47	46.18	54.92
Average farm size (acres)	2.14	2.33	3.02	3.12	3.33	4.14	4.08	4.00	4.50	5.64
Average family size	7.07	6.64	6.42	5.90	5.45	5.43	5.27	4.66	4.65	3.89
Per capita expenditure (M$)	150.00	197.00	225.00	255.00	289.00	327.00	369.00	419.00	514.00	820.00

SOURCE: Hazell and Roell (1983).

1. All household characteristic variables are evaluated at decile means.
2. Farm area is the operated paddy area.

Table 10. Marginal budget share by per capita expenditure decile in Gusau, northern Nigeria, 1976-77 (percent)

	Per capita expenditure decile[1]									
Group	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Commodity Group										
Food, alcohol, and tobacco	77.88	76.74	76.75	76.89	76.45	76.26	76.18	75.78	76.15	75.89
Cereals and cereal products	50.99	44.40	42.07	39.89	37.86	35.40	34.56	31.49	30.45	26.48
Fruits, vegetables, and nuts	4.57	5.94	6.71	7.61	8.18	8.59	9.56	9.68	10.41	11.72
Meat and fish	7.22	9.44	11.44	11.03	11.32	11.44	12.70	12.72	12.80	13.58
Eggs and dairy products	7.32	8.50	7.57	8.77	9.28	10.73	8.35	11.00	11.39	12.28
Clothing and footwear	8.87	9.08	9.31	8.94	8.98	8.96	8.85	8.92	8.56	8.31
Consumer expendables	4.23	4.33	4.44	4.45	4.47	4.39	4.72	4.49	4.57	4.66
Housing	0.45	0.48	0.45	0.41	0.43	0.46	0.34	0.42	0.37	0.32
Transport	1.49	1.98	2.04	2.27	2.52	2.77	2.62	2.88	2.95	3.16
Durables	0.77	1.21	1.36	1.33	1.33	1.37	1.54	1.65	1.71	1.91
Education and health	1.41	1.57	1.57	1.53	1.57	1.59	1.57	1.64	1.64	1.68
Personal services and entertainment	1.34	1.21	1.09	1.08	1.04	0.99	1.13	1.07	0.99	1.00
Social obligations	3.57	3.39	2.99	3.09	3.20	3.22	3.06	3.15	3.06	3.06
Locational group										
Food										
Home-produced	59.15	53.55	50.95	50.82	50.90	50.08	46.16	46.60	46.18	43.82
Locally produced	14.49	18.62	21.73	20.63	20.92	20.47	23.62	23.01	23.59	25.22
Imported	4.23	4.57	4.97	5.44	5.53	5.70	6.39	6.18	6.39	6.85
Nonfood										
Locally produced	10.95	11.05	10.56	10.73	11.02	11.21	10.93	11.24	10.94	10.96
Imported	11.17	12.21	12.69	12.38	12.53	12.53	12.90	12.98	12.91	13.14
Nontradables	26.96	29.22	27.61	29.29	30.49	32.06	30.11	33.09	33.75	35.61
Average farm size (acres)[2]	8.52	10.98	9.03	7.94	10.08	8.21	7.63	9.02	10.23	9.82
Average family size	12.52	10.48	7.66	7.31	7.66	7.69	5.62	6.24	5.45	4.61
Per capita expenditure (M$)	42.00	62.00	73.00	84.00	96.00	107.00	120.00	140.00	163.00	221.00

SOURCE: Hazell and Roell (1983).

1. All household characteristic variables are evaluated at decile means.

2. Farm area is the operated paddy area.

In Africa, on the other hand, marginal budget shares – the expenditures out of incremental income that are spent on nonfarm goods and services – were lower than in Asia. Twenty-four percent of the incremental income was spent on nonfarm goods and services in 1976-77 and 11% on locally produced goods and services. Moreover, the variations between different-sized groups in Africa were not high. This is because of the low absolute level of income in the African example compared with that in Asia. A much higher percentage of incremental income was spent on cereals, and marginal budget shares of incremental income spent on noncereal foods such as livestock and horticultural production were as high as 30%. They were also highly labor intensive or locally produced. The expenditure patterns of different-sized farming households in a sample of developing countries are shown in Table 8.

The stimulating effect on the rest of the economy by the consumption expenditures of medium-sized farmers on labor-intensive nonfarm goods and services, and therefore on the income and employment of the poor, is subject to three sets of leakages. First, larger farmers may have a higher propensity to save. The savings by large farmers, even though they constitute in the first instance a leakage from the consumption linkage, can serve an essential role as a source of investment to expand the productive capacity in the nonfarm sector and thus to increase the output of nonfarm goods and services in response to increased demand. Second, the increased output may lead to a fall in prices and a fall in income due to demand inelasticity. Third, the medium-sized farmers may follow capital intensive techniques, and therefore may not provide much employment either for the small farmers seeking employment or for the landless laborers.

The demand pull provided by agricultural growth needs to be matched by an elastic supply response from the nonfarm sector. In order for the rural nonfarm sector to respond strongly and positively to the stimulus provided by the increased expenditure of the farm sector, a few preconditions need to be met. Among them are infrastructures such as roads, transportation, communication systems, and electricity; rural credit to finance both current and investment costs of nonfarm activities; and education. The role of government policy in providing infrastructure, credit facilities, education, extension, and training to those engaged in the nonfarm sector cannot be overemphasized. Infrastructure reduces marketing costs, creates competition in the marketing structure by facilitating easy access, and encourages specialization within regions of a country in accordance with cost advantages (Ahmed and Hossain, 1988). Infrastructure development maximizes intersectoral linkages by enabling a decentralization of industrial and other nonfarm activities through a country. The development of market towns and small industrial cities is a very cost-effective way not only to prevent the growth of large industrial concentrations with their high social and economic costs, but also to decentralize industrial activities and bring them nearer to the source of demand and supply of raw materials and food.

An infrastructure that is highly dispersed throughout the country is needed. But this does not imply building roads or providing electricity in areas where either population densities or agroecological circumstances do not warrant profitable investment in either agricultural or nonagricultural activities. Agricultural research and research to design appropriate technology for labor-intensive, nonagricultural activities deserve high priority. The development of entrepreneurship is closely linked with the growth of institutions that are able to mobilize rural savings as well as provide credit to finance a wide variety of nonfarm activities. Education, both primary and secondary, also stimulates nonfarm entrepreneurial activities.

The critical role of infrastructure and rural institutions in strengthening intersectoral linkages is emphasized by the example of Africa, where the incremental share of nonfarm goods and services in country expenditures is low. The poor transportation and communication links between villages and towns have an important impact on the intersectoral linkages. These impede access to nonfarm goods and services and increase their cost relative to food prices. The role of infrastructure in the development of nonfarm sources of income and employment is illustrated with an example from Bangladesh (Table 11).

Table 11. Percentage increase in average income per household of developed villages over underdeveloped villages by income source

Income source	Increase (%)
Business and industries	20
Business	10
Industries	53
Wage income per capita	88
From agriculture	55
Not from agriculture	108

SOURCE: Ahmed and Hossain (1988).

Attempts have been made to quantify the impact on overall growth of a certain percentage increase in agricultural output. For example, it is estimated that an increase of $1 in agricultural value added would lead to an overall increase in GNP of $1.8 in Asia and $1.5 in Africa.

In a recent study of 34 developing countries in which agriculture was 20% or more of the GDP for the period 1961-84, it was found that a 10% increase in agricultural value added led to a 13% increase in nonagricultural value added. For the period 1973-84, the increase in nonagricultural value added was 14%. In a number of Asian countries, the increase in nonagricultural value added in response to a 10% increase in value added in agriculture varied from 2% in South Korea to 16% in Malaysia (Bautista, 1988).

The variations are due to differences in the relative importance of agriculture in national economies, and in the state of infrastructure and other factors that facilitate investment in the nonfarm sector. In a small country that depends predominantly on the export market for its nonfarm sector, in the way South Korea depends on its industrial exports, agricultural growth would be less of a stimulus to the development of the nonfarm sector than would be the case in other countries.

Similarly, in countries that depend on enclaves or exclusive export zones where agricultural exports are concentrated, and where at the same time technical progress is encouraged, the linkages of the export sector with the domestic industrial or nonfarm sector would be limited. This happened in colonial times, especially when production of a large-scale export crop was capital intensive and often owned by foreign investors, whose income was spent on imported goods and whose savings were transferred abroad.

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Linking Agricultural Growth with Growth in Other Sectors of the Economy in a Developed Country: The Italian Experience

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Introduction

The role and importance of agriculture in the structure of the Italian economy has changed dramatically over the last 40 years. Since the early 1950s, for the economy as a whole, and the early 1960s for the farm sector, international competition has been steadily increasing. For the farm sector, international competition came within the highly protected EC (European Community).

Regional disparities in sectoral and overall development were traditionally important in Italy and still are. Intersectoral linkages are deepening both within the food system and between the food system and the rest of the economy. Agricultural development has been strongly stimulated by the development of the urban sector, and through the labor market, the food processing industry, and increased availability of industrial inputs. Lack of agricultural development may be explained at least in part by weak industrial development and poor services.

Agriculture in the Development of the Italian Economy: Facts and Trends over the Last 40 Years

After a long period of international isolation during the fascist regime and the second world war, Italy began decisive moves to open its economy in 1946. At the beginning of the 1950s, the foreign sector was leading Italian development. Agriculture during the entire post-war period must be looked at within the framework of an increasingly open economy.

Farm interests were not particularly in favor of trade liberalization because backward conditions made Italian agriculture poorly suited to face international competition. Part of the industrial sector was no less backward, and in fact only the relatively more advanced subsectors of Italian industry were in a condition to push for faster liberalization. Even in those subsectors, difficulties with open borders were not minor, but access to foreign markets was viewed as essential for future development. From a more global point of view, opening doors to international trade was the only long-run option for a country so poor in raw materials and energy sources, with such a strong need for modernization.

In 1951, agriculture accounted for as much as 44% of the labor force and only 23% of GNP. Labor productivity in agriculture was little more than 50% of the average economy-wide labor productivity, but some small-scale industries and services were not in a much better situation. If development with industrialization and modernization was to take place, increased imports were needed, along with increased exports to pay the import bill. Although at that time there was an intense debate about the long-run perspectives of an open versus a closed economy, now it is easy to see that "the option facing Italy was not development in a closed economy versus development in an open economy, but rather industrial development in an open economy versus no industrial development, at least initially, in a closed economy" (Graziani, 1979).

European markets were the only accessible ones, and at the same time, the new political scenario at the world level was particularly favorable to integrate Italy into Europe, both politically and economically.

Continuously expanding exports was a must for economic development, and could be attained only by focusing on products in demand on international markets. Italy, therefore, was not to specialize in products for which it already had a comparative advantage, but had rather to attain a comparative advantage in those sectors with a more dynamic demand on international markets.

Internationally dynamic markets in the 1950s, particularly in Europe, were mainly for consumer durables originating from the mechanical and chemical industries, and Italy was able to show a particularly brilliant performance in those sectors in terms of export growth, with yearly increases from 14% to 17% from 1951 to 1962.

Export-led growth of manufacturing rapidly changed the structure of the Italian economy. In only 10 years, agriculture's share in the total labor force moved from 44% to 31%, and its contribution to GNP dropped from 23% to 15%. The process was not to stop: in 1970 agriculture's shares were 18% of the total labor force and 9% of the GNP, and in 1980, these shares were 13% and 7%, respectively. In only 30 years the country had radically changed its economic structure. Labor productivity in agriculture grew at a considerably slower pace than in other sectors, and as a percentage of the average for the whole economy, it was in still only slightly higher in 1985 than it had been in 1951.

Global figures obscure the regional differences that are traditionally so important in Italy. Highly dynamic, export-oriented, modern manufacturing sectors existed in the North very early, mostly within the Turin-Milan-Bologna triangle, while agriculture and small-scale traditional manufacturing prevailed in the Center and South.

Employment in agriculture as a share of total employment was 38% in 1951 in the Center-North and 57% in the South (*Mezzogiorno*). Ten years later the figures were 27% and 44%, dropping to 14% and 31% in 1970, and 9% and 24% in 1980. In the most recent year, agricultural employment in the Mezzogiorno was still above 20%, a level passed in the Center-North 20 years earlier, in the mid-1960s. In the early 1980s, farm workers were 23% of total employment in the Center-North, and 37% in the Mezzogiorno, compared to the early 1950s.

Labor productivity shows even sharper regional differences. Value added per worker in the Mezzogiorno in the Center-North was 75% in the early 1950s, 70% at the beginning of the 1970s, and 55% in the early 1980s.

Living conditions in rural areas were not only generally poor all over the country by the end of the war, but dramatically so in many regions, particularly in the South, and to a much lesser extent in the Center and North. In a country with more than two-thirds of its farmland in hill and mountainous areas, demographic pressure had heavily contributed to creating small and very small farm holdings. Also, political conditions following the economic crisis at the end of the 1920s had prevented any smooth process of land redistribution from the extensive latifundium still prevailing in most of the Mezzogiorno, and to a lesser extent in the Center, up to and including Tuscany's Maremma. In the Center and North, while little latifundium in a proper sense was to be found, social conflicts were growing under the new democratic conditions.

Over the centuries, *mezzadria*, a particular form of share-cropping, had been particularly successful in transforming most poor hill areas in the central and northern regions into relatively prosperous farms. Production was organized at the family level, and decisions were made jointly by the sharecropper (*mezzadro*) and the landlord. Over time, the landlord had come to be less and less of an entrepreneur, and more and more a rentier, while land scarcity still allowed him to get a major share of the farm output. In the Po Valley, entrepreneurial farming based on hired workers prevailed in many situations. Workers now had new political strength to ask for better salaries and working conditions, and medium- to large-scale farmers were already in the process of mechanizing most activities, but still heavily dependent on hired labor. With few nonfarm income opportunities for people back from the war, better access to land, land redistribution, and land reform were to become major political issues as early as 1944.

Political forces on the left were pushing hard for a general, country-wide, agrarian reform, while right-wing parties were strongly opposed. Christian Democrats, the center moderate ruling party, had internal conflicts, with a wide popular based and many populist leaders favoring agrarian reform in moderate terms, and interest groups linked to landowners' entrepreneurial farming opposing it. In 1950 land-reform laws were approved for most regions in the South and Center, as well as a minor area in the most depressed Polesine at the delta of the Po River. By 1955 what was supposed to be the first step toward more general country-wide agrarian reform was completed.

Meanwhile social and economic conditions had been rapidly changing, with the industrial sector in the North booming, and peasant labor migrating mainly from the South to the North, and to Central Europe. Within the new, more optimistic economic environment, and with political equilibrium more favorable for the center-moderate ruling forces, the claim for generalized agrarian reform rapidly lost most of its strength. At the time the Treaty of Rome creating the European Economic Community (EEC) was signed in 1958, generalized agrarian reform was no longer a major political issue. In order to compete openly with some of the most advanced European agricultural economies, priorities had to be completely reformulated. Restructuring and modernizing traditional small-scale agriculture, and creating adequate market structures and organizations became the major concern as Italian agriculture entered a completely new stage.

The limited agrarian reform led to the expropriation of some 700,000 ha, affecting 10% of all holdings above 50 ha, two-thirds of those above 1000 ha, and all above 2500 ha (Marciani, 1966). Expropriated lands were initially in extremely poor condition, and a major investment was necessary to make them viable small farms, including basic land preparation, new housing, roads, and infrastructure development where in many instances there was none. Over 113,000 new small holdings were created with an average size of 5.5 ha.

Even though the expropriated land was taken from a limited portion of Italian agriculture, and the landlords were left with the best part of their holdings and were paid close to market value, it was still a deadly coup for the political power of the rentiers. Scared by the possibility of wider reform, those not willing or able to get into entrepreneurial farming sold land in a market where demand was sustained by a policy of strong subsidies for the creation or reinforcing of small-scale family farms. The aim was to transfer land to farmers through market mechanisms. The indirect effects of land reform – to promote a wider redistribution of land – were estimated to have been no smaller than the direct ones. Other subsidy programs eased access to credit, and lower fuel prices for farm use provided incentives to buy farm machinery. Together, these programs have contributed to the creation of political consensus, social stability, and economic welfare for small farms which was rarely known before.

Later, with many nonfarm income opportunities available in most regions, rural family incomes found new stability as part-time farming came to prevail.

From the point of view of efficiency, problems could not to be solved by creating or strengthening a farm structure dominated by small farms. In fact, farms created by the land reform appeared to be too small by the end of the 1950s, both in terms of cost structure and their capacity to provide an acceptable family income. Efficiency and cost issues acquired increasing importance as the country joined the European Community, and Italian farmers started to experience previously unknown international competition.

Joining the EC was clearly not an easy business for Italian agriculture. All the modernization efforts of the 1950s were largely insufficient to put Italian farmers in shape to compete with the French, Dutch, and Germans. Farm size was an important aspect, but certainly not the only one. Technologically, financially, and managerially, most Italian farmers were not in the best position to enter international competition. The problem was not completely at the farm level. Marketing and processing structures were inadequate. Comparative advantages seemed to be confined to fruits, vegetables, and wine, while disadvantages were most serious in grains, meat, and dairy products. EC protection and price supports differentiate heavily among products and also discriminate against those countries with relative advantages in the less-protected commodities. From the 1960s, Italy has increasingly become a net importer of food and farm products, largely failing to counterbalance the increasing imports of grains, meat, and dairy products with its "Mediterranean" exports of fruits, wine, and vegetables. In recent years the farm deficit has been second only to that for oil and other energy sources.

Agricultural Labor for the Urban Sector and Industrial Inputs for Agriculture: A Difficult Exchange

At the beginning of the 1950s, Italian agriculture was still mostly based on human and animal labor, but since the beginning of the century, mechanization had made considerable progress in some areas, notably the Po Valley. But country-wide, agriculture entered the 1950s in a state of radical change, and in just two decades a deep technological transformation was completed. In the 1970s machines had already replaced most if not all animal labor, and today a horse or a donkey working on the land is little more than a picturesque detail for the tourist in most remote areas.

Mechanization spread all over the country, but substituting machines for human hands and horses was particularly difficult on steep slopes and in mountainous areas. But these were exactly the areas where the migration of rural labor was particularly intense because of poorer living conditions and lower productivity levels. Size, on the other hand, was a more general obstacle to mechanization, because small farms were often too small to use farm machinery effectively.

Where labor substitution was more difficult, following an out-migration so massive as to be called an exodus by most observers, traditional farming based on cheap labor entered a period of deep crisis. Traditional labor-intensive techniques were appropriate, although with different levels of productivity, to a wide variety of local situations. Relatively steep slopes were not a tremendous obstacle. Soil fertility could be maintained with appropriate farming techniques, and some areas were able to reach a relatively high level of prosperity in a traditional environment, using high levels of labor for farming practices as well as long-term investments to the land. In extreme cases agricultural land had to be reclaimed before it could be used for intensive farming, and many long-term efforts may still be seen in rural landscapes all over the country.

Difficulties in using machines on sloped lands are the main cause of a sharp decline in farming and rural activities in most hill and mountainous areas, but certainly not the only ones. In a broader sense, these areas, often referred to as "internal" (*aree interne*), become increasingly peripheral to the distribution of economic development. Development is a cumulative process in many senses, including spatial. Industrial plans and services are increasingly located in or near the most important urban areas, and along main communication lines and transportation corridors. Farming modernization, while so difficult in peripheral areas on slopes, is much easier in the main valleys and coastal areas. Improved technological conditions accompany better market opportunities the closer farming comes to the urban environment.

Traditional peasant economies both suffer and enjoy a certain level of isolation. Isolation is imposed by the environment and poor communications, as well as by poor market opportunities. Isolation implies that some opportunities may be lost, but it also implies that activities not competitive on broader markets may be possible to maintain locally. Typical of such an isolation-based equilibrium are highly diversified farming and nonfarming activities. The same logic applies to individual farms and the local community: diversified production makes the best use of the available labor force, and at the same time provides a better match for consumption needs.

Opening up communications exposed low productivity to competition from areas where the modernization process had been much more rapid, smooth, and successful. Nonfarm wage income flowing into the local community made it feasible to buy on the market what had previously been locally produced. And with labor flowing out through rural-urban migration, the very condition for maximum diversification in this sort of economy -- abundant cheap labor -- failed

Technical change is also a cumulative process. Mechanization tends to accompany adoption of new varieties, better seeds, fertilizers, and pesticides. Innovation packages, rather than individual innovations, tend to be the rule. Constraints to mechanization in these areas impeded broader technological change. But at the same time, nonmechanical, biological, and chemical innovations were also much scarcer for hill farming and for mountainous areas, simply because innovations came from areas where farming was not done under such adverse conditions. Farm labor was becoming increasingly scarce, it was difficult to find a new technological basis for farming, and many activities simply had to be abandoned while farming became more extensive. In many cases, farming per se ceased to be a relevant activity since the increasingly small farms could not be enlarged through the purchase of small plots of land.

Land is not supposed to be only for farming: it is a place to live, to dream, to stay in the future, to dream of doing something better as a farmer in an improbable future. Migrants owning a plot of land often did not sell it even though they stopped farming. Quite often buying a piece of land became the typical investment for family savings with little alternative opportunities. In that way farming became less intensive without farm holdings becoming larger.

The limited size of farms is a general limitation for Italian agriculture. With farms too small, agricultural activities in general and mechanization in particular cannot properly minimize costs. In coastal plain areas this has tended to become the main problem. Increasing nonfarm use of land for industrial and recreational purposes and the expansion of urban areas have made good agricultural land even scarcer. But with no slope-specific obstacles to mechanization, technological change in flatlands was adopted without any particular difficulty, deeply and sometimes radically transforming the rural landscape. Crop diversification, once the rule, was sharply reduced and replaced in many cases by monoculture. Fruits and vegetables, as well as animals, had almost disappeared during the 1960s and 1970s from areas where they had once been quite common.

Since the early 1960s, agricultural development has become more and more concentrated. Extended areas in hill and mountainous regions, once a most important part of Italian agriculture, now have a relatively minor role, both in terms of output and employment. The share of total agricultural output from the flatlands was 42% in 1955, 45% in 1960, 48% in 1970, and 52% in 1982 (Fabiani, 1986). Technological bottlenecks, unequal distribution of services, and industrial development are the main factors which explain the different growth rates. With initial values set at 100 at the beginning of the 1950s, 30 years later total farm output was 200-260 in regions such as Lombardy, Emilia-Romagna, Veneto, Lazio, Abruzzo, Campania, and Puglia, with agricultural growth concentrated in flat, irrigated areas. At the other extreme, farm output was below 200 in all the other regions, and as low as 110 in Liguria, 146 in Valle d'Aosta, 168 in Calabria, and 174 in Sicily.

Average farm size in Italy is particularly small, but for a huge number of holdings, it is extremely small. Currently, people tend to refer to a 20-ha farm (which in many other European countries would be considered small) as medium-sized. The great majority of farms are even smaller, just a few hectares. Physical size is a poor indicator of economic dimension, but even when land quality and capital are considered, most Italian farms would be classed as small to very small by international comparison. Making a living for the whole family from farming alone is quite often an impossible task, and this is the reason that today more than half the farms are part-time farming operations.

Full-time farming on particularly small plots is the joint result of few nonfarm jobs and the difficulty of enlarging the farm where good agricultural land is so scarce. Under such circumstances, family farm labor tends to be relatively abundant and cheap, which in turn is the basis for intensive diversified farming. Switching to part-time farming is primarily the consequence of access to better income opportunities beyond the farm gate, without being forced to completely quit farming as an independent job. This typically occurs where an external job becomes available within a relatively short distance. But quite peculiar to the Italian experience since the 1960s, part-time farming has also become associated with long-distance commuting and even with migration abroad. Two quite different reasons help to explain such intriguing behavior:

1. Neither independent farming nor the new job alone could provide a satisfactory income for the family.

2. Since the 1950s, a very important proportion of Italian migration has been transitory, with the migrant worker leaving and coming back within 12 months in a long chain of departures and trips back home.

In the early 1970s, the proportion of repatriations following a stay abroad of less than 12 months compared with total repatriations was above 80% in Calabria and Basilicata, and above 50% in most of the southern Mezzogiorno. Migration to other European countries mostly involved only male workers, who eventually settled down again in their original village, town, or region (Gorgoni, 1980). Quite often the family stayed at home, children were raised there, and investment plans centered around a better or new house, starting a new small-scale business, or once again trying modern farming. But even when farming per se was not a goal, the small plot of land, if there was one, was not sold, and so rural-urban migration drastically reduced the availability of labor for agriculture (De Benedictis, 1980).

As the family starts getting a significant proportion of its income from nonfarm activities, producing for own consumption rapidly loses its relevance because most goods are better bought on the market. With rapidly decreasing labor availability on the farm, on the other hand, crop diversification and highly labor-intensive techniques are not the best choice any more. Instead, as extra-farm activities tend to prevail, labor becomes a scarce input even for small family farms, and mechanization increases. Production is increasingly for the market, and due to reduced farm size, specialization emerges if cost efficiency is to be attained. With scarce labor and the mechanization difficulties associated with small farms, the development of a sector selling specialized services such as soil preparation, harvesting, pesticide treatments, etc., has become important. This sector has a largely farm origin, but its diffusion is far from even; it is stronger in more advanced areas, and minimal in the more backward and peripheral ones.

Along the Food Chain: Selling to and Buying from the Farm Sector

The opening of a massive urban market for the initially abundant farm labor is probably the most pervasive linkage between agricultural and nonagricultural growth in the Italian economy. As farm labor becomes increasingly scarce in relative terms, modernizing agriculture implies the adoption of labor-saving innovations. But in a country where good agricultural land has traditionally been scarce, land-saving innovations are also needed. In fact, good agricultural land becomes scarcer during the modernization process, even in absolute terms. Some land, and not infrequently some of the best, is lost by the expansion of urban areas, industrial plants, and infrastructure creation.

The fact that both farm and nonfarm development is concentrated mainly along the coast, in flat areas, and along the main valleys, which are also the densest areas of the population, causes intense competition for land between the farm and nonfarm sectors. On the other hand, moving toward a new technological environment where machines and engines substitute for animal and human labor, many areas previously suited for farming, although with relatively low productivity, now become marginal because it is difficult to efficiently mechanize farm operations on sloped fields. A more elastic land supply would create larger farms in these areas, somewhat easing mechanization problems, but since migrants leaving farming often do not sell the land (nor do they rent it because of an unfavorable law on land rental), one obstacle reinforces the other. The outcome, however, is not less mechanization and technological change in general, but rather a less efficient, more spatially concentrated pattern of modernization. Nor is there any option with less technological change. Once the doors are open to market forces, even initially remote rural communities have little chance of surviving without change. Initially remote poor areas must now compete with more centrally located, better endowed areas, and in an open economy, both must be able to compete in an international context.

For Italy, starting in the early 1960s, the relevant international environment included the advanced farm sectors of the Netherlands, France, and Germany. However, domestic differences were sometimes greater than international ones. For the peasants in Calabria and Basilicata, competing with farmers in Emilia and Lombardy was no easier than for the latter to compete with Bavarian or Dutch farmers. Initially, opening the farm sector to foreign competition directly involved only part of Italian farming, but indirectly and in the long run, the country-wide rural economy was forced to change. Change was badly needed by all farms and areas, but was obviously not equally accessible to all.

Changes in consumption patterns were not minor. Food consumption as a share of total household expenditures was 47% in 1951, 35% in 1970, and 28% in 1982. During the same period, bread and pasta as a percentage of total food expenditures dropped from 26% to 13%, fruits and vegetables rose from 15% to 21%, and meat products rose from 42% to 54% (Fabiani, 1986). As a share in total meat consumption, beef dropped from 40% to 34%, and lamb from 6% to 2%. Poultry and chicken jumped from 11% to 25%, while pork increased slightly from 26% to 28%. In line with the general pattern of economic development, initial increases in per capita income from relatively low levels brought higher food consumption with relatively minor changes in the food basket. Then substitution started taking place: not only was the per capita food basket larger, but it also had more animal protein and less fruit. Eventually most of the marginal increases in food expenditures were not from buying more food, but from buying more highly processed and marketed food.

Looking at the food system as a subset of the national economy, including goods and services sold to farmers and processed goods bought from farmers and then sold to consumers, Italy is the same as other economies. Farming as part of the system becomes smaller and smaller in relative terms, and at the same time, more and more integrated into the total economy.

Compared with other EC countries, intersectoral linkages within the food system and between the food system and the rest of the economy are still relatively weak in Italy. But the change over time is impressive, and the direction of change is the same as in other more advanced economies (Fabiani, 1986). Regional differences in the development of other components of the food system are even greater than those observed for farming.

Regions in the Center and North account for 80% of the national food processing output, but only for 60% of farming output (Balestrieri-Terrasi, 1985). The ratio of value added in farming to value added in food processing dropped from 3.0 to 2.4 for the country as a whole between 1970 and 1982, but from 2.2 to 1.8 in the Center-North, and from 5.8 to 4.6 in the southern Mezzogiorno. In terms of employment, regional differences are even sharper. Between 1970 and 1982, the ratio of farming employees to food processing employees dropped from 5.4 to 3.4 in the Center-North, but only from 13.2 to 9.7 in the Mezzogiorno.

Looking at the food system as a whole, rather than just at farming, regional imbalances in industrial development are certainly no less important than differences in growth rates for farming. In fact, there are reasons to argue that the development of farming was frustrated by a lack of adequate development in food processing. This might apply to the whole Mezzogiorno as well as to most hill and mountainous "internal" areas, where industrial development in general and food processing in particular are even weaker, in relative terms, than agricultural development (Gorgoni, 1987).

Industrial sectors selling inputs to agriculture are even more concentrated than the food processing industry. New plants built in the South by both the private and public sectors have not dramatically changed the situation. It is not that large-scale mechanical and chemical industries are still mainly in the North, but more significant is the weak development of small- to medium-scale industry in most of the South, in sharp contrast with the North and part of the Center. There has been an effort to foster development in the South along the lines of what has come to be known as the Emilian or Adriatic model (which has to do with a particularly happy blend of development in small-scale industry, farming, and services). Although not completely frustrated, this has shown clearly that there are no easy shortcuts, that history, social structure and social values are most important, and that efforts by the public sector alone are not enough if they don't succeed in also activating private business.

Agriculture's decreasing importance within both the food system and the national economy goes far beyond its declining shares in total output, value added, and employment. No less important is the fact that the farm is less and less a locus of entrepreneurial decision making. As economic development progresses, an increasing number of decisions originally taken at the farm level are transferred to either the input supply or to the food processing sectors. Process and product innovations are both too big for farmers. In a sense, the farmer becomes more and more the peripheral executor of decisions taken outside the farm sector. Research and development of new products and processes are simply out of the farmer's reach. Farmers could have some access through the public sector, but the public sector in Italian agriculture has been particularly weak in research and extension. Technical assistance to farmers is increasingly done by the very same commercial firms selling inputs and/or buying outputs. This is obviously not without many advantages for farmers, but clearly they become less and less free, independent entrepreneurs. And what happens within the farm sector is increasingly determined and decided outside of it.

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Session II
Summary

Linking Growth in Agriculture with Growth in the Rest of the Economy: Research Policy Implications

Introduction

The Session was introduced with a concise but comprehensive overview by Islam of the linkages of agriculture to the overall economy, followed by an interesting account prepared by Gorgoni of the linkages of agriculture with a vibrant industrial sector, as in the case of Italy. While Islam framed his presentation from the perspective of the developing countries, Gorgoni's picture of sectoral linkages was through the lens of a developed, industrial economy.

Italy was chosen by the organizers because that country's experience illustrates the nature and dynamics of agricultural linkages with the rest of the economy at a stage of economic development which many developing countries may experience in the future. Moreover, the Italian experience provides a concrete example of the interactions of agriculture in regions with widely different factor endowments, and their interactions with the agriculture of neighboring countries in a relatively liberal trade environment.

Intersectoral movement of production factors and the central role of agriculture

Islam's presentation detailed the nature of the linkages between agriculture and the nonagricultural sectors of the economy. The linkages are many, and they operate through the intersectoral movement of production factors, labor, and capital, as well as of goods and services. And at the center of these linkages is agriculture, which in most developing countries provides the principal source of national income, employment, and foreign exchange. In turn, these resources are mobilized and channeled to support growth in other sectors of the economy.

In addition, Islam defined two types of intersectoral linkages involving agriculture, consumption linkages, and production linkages. The consumption linkages of agriculture occur when income generated in the agricultural sector is spent on a variety of manufactured consumption goods, as well as on services such as housing, transport, education, health, and personal services of all types.

There are two types of agricultural production linkages. Forward production linkages involve processing, marketing, distribution, and the further fabrication of agricultural goods for use in the nonagricultural sector. The trade and commerce sector in developing countries, especially in rural areas, is predominantly engaged in the marketing and distribution of agricultural commodities. The higher the stage of industrialization, the greater are the forward production linkages for agricultural products that are processed and fabricated in the domestic sector.

The backward production linkages of agriculture arise when industrial inputs such as fertilizers, pesticides, irrigation equipment, and mechanical equipment to grow and transport agricultural commodities are used by the agricultural sector. At lower levels of agricultural development, the percentage of such purchased inputs in agricultural production is rather low. However as agriculture is modernized over time, the proportion of purchased inputs to total gross output rises.

Thus in countries where agriculture either accounts for a large percentage of national income or provides a major source of employment, the growth linkages generated by agricultural development are likely to be high because the impact on the total economy through consumption and production linkages is likely to be high. Consequently, technical progress in agriculture leading to increased production and higher income in the agricultural sector stimulates overall growth.

This supports the earlier argument of Schuh (Session I) that the benefits of agricultural research should be sought more widely in the economy, rather than from the producer side alone, to provide a sounder basis for agricultural research policy.

Linkages of agriculture in an export-led industrial economy

Gorgoni provided the backdrop for Italy's recent agricultural history:

- a limited resource base at the farm level with relatively small farms, and for the most part sloping, marginal land, particularly in the south;
- increasing open competition from its agriculturally better-organized and better-endowed European neighbors;
- development unfolding in the context of regional dualism running roughly parallel to a sector dualism -- the industrial north versus the agrarian south.

Emerging prostrate from the Second World War after decades of isolation, Italy had no recourse but to open its door to international trade as the only long-run option for a country so poor in raw materials and energy sources, and in such dire need of modernization. This liberal trade policy was reinforced and made more formal when Italy joined the European Community, which was established by the Treaty of Rome in 1958. The strategy proved highly successful, and within 30 years, export-led manufacturing growth rapidly changed the structure of the Italian economy.

The industrial success accentuated the north-south economic disparities, measured in terms of farm productivity, share of agriculture in employment, labor productivity, and ratio of value added in farming to value added in food processing. Intersectoral linkages in Islam's presentation for the most part reflected the dominant flows of growth-inducing potential from agriculture to the nonfarm sector. In Gorgoni's Italy, the roles were reversed. Agriculture was at the receiving or responding end of the initiatives generated by industry. Gorgoni described changes in consumption patterns from bread and pasta to dairy, livestock, and fruits as a consequence of per capita income growth; the development of greater value added in food processing as a response to changing demand, as well as from direct influences of industry; and the massive outflow of labor from agriculture to industry. He spoke of the "difficult exchange" of agricultural labor for industrial inputs between the two sectors.

Among all these, Gorgoni concluded that the opening of a massive urban market for the initially abundant farm labor was the most pervasive linkage between agriculture and industry in the Italian economy. The outmigration of labor from agriculture, however, occurred not only to the industrial Italian north, but also to other countries in Europe.

Intersectoral linkages and a balanced growth strategy framework

As a guide for the discussions, two questions were posed to the working groups:

- Considering intersectoral linkages in developing countries, what are the most important bottlenecks hindering agriculture from contributing to the growth of the economy, and those hindering other sectors of the economy from contributing to agricultural growth?

- What are the necessary development policy and research policy actions?

Islam's initial observation that the intersectoral linkages of agriculture are many and varied proved prophetic as each of the five working groups came up with a different framework for systematically looking at intersectoral linkages.

One working group, however, felt obliged, before deliberating on the linkages and bottlenecks, to place these linkages in the context of the overall process of structural change taking place in the economy. For this purpose they found the balanced growth process and input/output relationships to be useful conceptual bases for their discussion.

The working group emphasized the need to recognize that several key macro variables determine the context within which the exchange between agriculture and industry takes place. Fiscal, monetary (particularly exchange rates), and wage policies determine the level of activities and relative prices for production factors and goods. The frequently cited problem of bias against agriculture often finds its root causes in the policies that govern these macro variables. Moreover, the urban bias is often reinforced with excessive infrastructure and services for towns and cities relative to, and at the expense of, the rural areas, and by food price policies that turn the terms of trade against agriculture.

The consistent bias against agriculture that the working group identified as a problem in many developing countries suggests a clear lack of intersectoral policy and lack of political commitment to a balanced growth strategy, which by implication the working group thought appropriate to the conditions in many developing countries.

This issue of balanced growth and intersectoral competition for resources was referred to by Islam in the plenary when he observed that "resources are predominantly realized from the agricultural sector, which in the early stages of development is inevitable." Islam continues, "what is critical is whether the resources so mobilized in the agricultural sector are invested within that sector to an extent that is commensurate with its needs and the opportunities it provides for profitable investment."

Bottlenecks and Impediments to Intersectoral Linkages

Consumption linkages

As noted by Islam, the consumption linkages of agriculture in developing countries -- creating a market for nonagricultural consumption goods and services -- are in practice stronger than the production linkages. The discussions saw two bottlenecks to the further exploitation of these consumption effects in many developing countries:

- unsatisfactory or low purchasing power of farmers;

- unequal distribution of income within the rural community.

Obviously there will be little consumption spillover to the rest of the economy if farmers in general have low purchasing power. The second concern, the inequality of income distribution as a constraint to agriculture's potential to contribute to the total economy via consumption, follows Islam's observation that as agricultural incomes expand, a higher proportion is spent on nonfood goods and services. As such, poorer farmers tend to spend more of their household incomes on food, and therefore, their consumption effects on the rest of the economy are limited. On the other hand, middle- and high-income farmers tend to spend more of their additional income on nonfood goods and services, and therefore, their spending patterns stimulate more growth in other sectors.

Forward production linkages

"The forward production linkages consist basically of processing, marketing, distribution, and the further fabrication of agricultural goods for use in the nonagricultural sector." This quote from Islam's paper emphasizes the range and scope of agriculture's forward production linkages, and also the working groups' common recognition that agriculture's role goes beyond being a primary supplier of food and raw materials.

The bottlenecks or impediments cited by the working groups included:

- irregular supply and quality of raw materials;
- lack of appropriate processing technology;
- underdeveloped markets, poor or nonexisting marketing channels, including lack of organized market information;
- inadequate storage facilities;
- lack of incentives to rural entrepreneurs;
- lack of skilled manpower and entrepreneurial skills;
- policies which favor food imports;
- general lack of incentives to domestic processing of agricultural products.

Backward production linkages

Agriculture's potential to create a demand for fertilizers, chemicals, equipment and machinery, and other production inputs and services from the other sectors of the economy is constrained by:

- inadequate supply and high costs of inputs due to poorly developed input industries, overprotection, and undeveloped product markets;
- inappropriate inputs and equipment and technologies which do not meet the scale, factor endowments, and technical needs of agricultural producers;
- low investments and low capital formation in agriculture;
- inadequate extension services.

Development and Research Policy Actions

Need for a framework for intersectoral policies – A balanced growth strategy

One working group advanced a framework for studying intersectoral policies and argued that a balanced growth strategy was crucial for developing countries. In the absence of a framework, policies will be fashioned piecemeal to address narrow sectoral concerns, to the neglect and detriment of desirable intersectoral complementarities and linkages.

While the mobilization of resources out of agriculture to stimulate the rest of the economy may be inevitable in the early stages of industrialization, the process should not put into jeopardy the ability of agriculture itself to sustain its own growth and, therefore, its capacity to get the rest of the economy moving. A balanced growth strategy presupposes a careful balancing of the needs of the different sectors, including agriculture, and should act as a brake against the pendulum swinging excessively in one direction.

Consumption linkages and equity in agriculture

Although consumption linkages were described in the plenary as exercising a greater impact on the economy than production linkages in the present context of many developing countries, only two major policy issues appear to have emerged in the discussions. First is the need to improve the purchasing power of producers, and second, the need to address the inequality of income distribution in the rural community.

The first concern overlaps and is partly addressed in the previous section, which advanced the need for a balanced growth strategy to curb the excessive bias of governments against agriculture, and thereby improve the domestic terms of trade for agricultural producers.

The second concern goes back to the statement by islam that the magnitude of consumption effects of agriculture depend partly upon the distribution of income in the rural areas, especially the distribution of the incremental income that accrues to various farm families. He argues that middle-income farm families demonstrate the most desirable pattern of household expenditures because they tend to spend more on labor-intensive, domestic, nonfood goods and services.

Unfortunately the working groups that raised the issue of unequal distribution of farm income did not follow through on this point because the argument is susceptible to a number of different possible conclusions. For example, does this imply a policy objective to shift the majority of producers who are small and poor as fast as possible into the ranks of middle-income producers? Or does this suggest, more narrowly as a matter of strategy, given the usual constraint of limited resources, a policy of focusing on those small poor farmers who have the most potential to become middle-income producers?

Production linkages and development policy actions

The development policy actions to strengthen forward and backward production linkages have so much in common that they are more easily treated together. The policy actions suggested by the working groups included:

- improvement of rural physical infrastructure: farm-to-market roads, communications, rural electrification, transport, and storage facilities;

- improvement of rural institutional infrastructure: development of factors and product markets, including improvement of market information systems, strengthening credit and other financial intermediaries, promotion of farmer organizations, and improvement of research and extension delivery systems;

- provision of technology appropriate to the scale and factor endowments of producers: appropriate processing, storage, and transport technology for agricultural products, as well as appropriate input technologies – suitable equipment and farm inputs;

- promotion of rural-based enterprises: domestic processing of agricultural raw materials, rural manufacturing industries — cottage, small-scale, and light industries — and rural services such as retailing of farm equipment, housing, and transport;

- human resources development: training rural entrepreneurs, training skilled manpower for rural industries, and overall improvement of rural education opportunities.

Research policy actions

Need to develop social science research capacity on the intersectoral linkages of agriculture. The long research action agenda brought out by the working groups collectively pointed out the need to better understand the nature and dynamics of the intersectoral linkages of agriculture. One working group noted the tendency of research in most developing countries to take a rather "narrow view and not adequately cover the linkage aspects." Thus the first priority was the need for social science and policy research capacity on the broad interactions of agriculture with the rest of the economy.

Specific research priorities. The broadening of the research agenda to include research on the linkages of agriculture opens up an array of researchable topics. One working group described this broadening as a research agenda on the whole food chain, from the goods and services that go into agriculture, to primary production itself, and the processing, handling, and distribution of agricultural produce.

In relation to consumption linkages, the following priority research topics were identified:

Causes and origins of policy biases against agriculture — this concern reinforces the main theme of the previous session, but in the context of low consumption effects from agricultural producers due to the systematic discrimination against agriculture.

Impact of agricultural income distribution to overall economic growth — the summary data presented by Islam on the impact of rural incomes on consumption linkages in a few countries need to be further validated in specific countries, hence the general interest to do similar studies in many countries as formal bases for policy. This research will include surveys of rural household incomes and expenditures, and their patterns among different income classes.

The research priorities associated with production linkages — these included social sciences (including economic components), as well as natural sciences and agricultural engineering dimensions.

Impact of rural physical infrastructure on productivity of agriculture per se and the magnitude of its linkages — while the need for more and better rural physical infrastructure to support agriculture is generally understood and accepted, the data from IFPRI's work in Bangladesh, which was presented very briefly in the plenary, impressed many participants as the kind of evidence that agricultural research systems in developing countries should use to support the claims of agriculture for its fair share of investments in infrastructure. It can be demonstrated that the benefits from rural infrastructure accrue not only from agricultural productivity, but even more so from agriculture's expansionary impact on the rural economy.

Research on markets — the discussions on the markets for goods and services that flow into agriculture and the markets for agricultural produce, particularly those that involve further processing, stimulated a broad concern for market research on the factors of production, including land, and products and services associated with the whole food chain. This will include studies on marketing channels, associated costs, and farmers' needs for better and more timely market information. The opportunities for developing regional markets were also pointed out.

Research on appropriate technologies — this need was prompted by several remarks made in the working groups on the general lack of processing as well as input technologies appropriate to the scale and factor endowments of the farmers. Some of the more specific items mentioned included:

- more research on processing, storage, handling, and distribution of agricultural produce;

- more relevant research on inputs: chemicals, machines, and equipment adapted to the needs of producers;

- closer links between NARS and cottage and small-scale industries and other agricultural enterprises.

Research on rural enterprises and rural entrepreneurship — the research agenda will likewise include studies on the industries and enterprises linked with agriculture. More specifically this will entail studies on:

- on-farm and off-farm employment;

- skilled labor demand by intermediate industries;
- labor-intensive rural industries;
- rural retailing as a major service industry;
- promotion of entrepreneurial activities, enhancement of entrepreneur skills, and skilled manpower needs;
- credit needs of rural industries.

Research orientation and strategy

Research on growth centers and target sectors. One working group came out very strongly for a research strategy to design research and development around the related concepts of regional comparative advantages, growth centers, and target segments of the farming population.

At first glance, this appeared to go beyond the session's immediate topic. However, when one considers the broadening of the research agenda suggested by these deliberations, there seems to be a need to focus on specific issues that will contribute to policy objectives as opposed to other competing research concerns.

NARS collaboration with other institutions in addressing intersectoral linkages issues. Finally, one working group sounded a note of caution by recognizing that many of the researchable problems mentioned may be beyond the capacity and comparative advantage of many NARS. Thus the working group believes that the NARS should make every effort to interact with other research groups, such as those in planning and finance, in the national universities and in the international community, which are better able to tackle these issues.

Moreover some of the new technology generation requirements may be beyond the capacity of some NARS, particularly the smaller NARS. Similarly, the NARS as a matter of strategy, should seek every opportunity to solve common problems cooperatively with other NARS, and to explore prospects of transferring and adapting technologies developed by other NARS which may be further along in the agricultural modernization process.

Session III

Sustainability of Agricultural Production Environments

The Agricultural Sustainability Issue: An Overview and Research Assessment

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Introduction

There is a growing and diverse literature based on agricultural sustainability – concerning its meaning, relevance as a concept in agriculture and development, and applicability for research planning and extension activities. Some confusion comes from the fact that the term has intellectual (and emotional) roots from different disciplines where it is used in a variety of contexts (Brown et al., 1987).

By way of introduction, I discuss several meanings of *sustainable*, then, of *agricultural sustainability*, followed by a look at our current agricultural system and what the impetus is to change it. Then, I report the state of the art in research on low-input, sustainable farming systems and consider what impediments there are for farmers to change from current agricultural production systems. Finally, I conclude by looking at the agenda for change and note that any transformation is more likely to be gradual than abrupt.

Perceptions of 'sustainable'

Sustainable to some means survival – barely hanging on. A subsistence-level or sustenance-level livelihood is endured by much of the world's population.

The term *sustainable* has long been used by resource managers with reference to the maximum harvesting of forests or fisheries consistent with the maintenance of a constantly renewable stock. The same concept applies to the optimal use of a groundwater aquifer. *Sustainability* is the steady state when what is being used (harvested) is continually replaced.

Sustainability has been defined by some in terms of carrying capacity (a term developed by population biologists) – the maximum population size that the environment can support on a continuing basis. As one would expect, calculation of carrying capacity for society on a regional or global basis is exceedingly difficult because "quality of living" must enter the equation.

Lester Brown (1981) sees a sustainable society as enduring, self-reliant, and less vulnerable to external forces. He optimistically asserts that this can be accomplished with regulations, efficient use of resources, conservation, and a stationary, dispersed population with less affluent lifestyles.

Conventional economic theory has a more neutral outlook lacking a direct counterpart to sustainability. Given the proper social discount rate, resources, properly priced, can be allocated efficiently to yield their highest return over a specified time horizon. Technological innovation is an integral part of the theory dispelling great concern for natural resource exhaustion and for the environment's potential degradation. Hence, with occasional technological breakthroughs, population growth is not inconsistent with economic growth, nor with a dynamic market equilibrium. Distinguishing between public and private costs is a key problem, however, in dealing with environmental degradation.

The concept of agricultural sustainability

With this general discussion as background, we turn to the concept of agricultural sustainability. Other terms for agricultural sustainability include alternative, regenerative, low-input, ecological, environmentally sound, and even organic agriculture. These terms are used by people interested primarily in alternative systems of farming that will feed expanding populations while minimizing potential negative effects, whatever they might be. Defining the negative effects essentially separates or categorizes the various proponents of sustainable agricultural systems. Some groups put primary emphasis on minimizing environmental damage and degradation. Sustainability becomes almost synonymous with stewardship of the earth. Others want mainly to perpetuate a rural community system; community sustainability or maintaining viable rural communities becomes almost a goal in itself. Still others equate agricultural sustainability with food self-sufficiency while minimizing costs. Many advocate an energy-conservation agriculture — so much so that efficiency of the system is measured exclusively in terms of energy use. People require both safe food and water, which in turn, proponents argue, require an agricultural system that can operate ad infinitum with only meager dependence on inputs external to the farm. Thus, just as the term *sustainability* has differing dimensions in various contexts, the agricultural counterpart has social, ecological, economic, and emotional connotations.

Harwood (1987) listed the following dimensions of the agricultural sustainability concept, important for both the developed and developing world:

- *The time dimension.* Farmland preservation and soil conservation continues over centuries toward distant horizons.

- *Social sustainability.* The farm family and traditional rural community are believed to be able to endure over time, even with changes in the general farm economy.

- *Economic sustainability.* The farm unit is expected to remain economically viable in the long term; smallness and diversification are emphasized.

- *Maintenance of soil and genetic resource bases.* A diversified gene pool is a buffer necessary for long-term survival.

- *Minimization of environmental pollution.* The changing human/land ratio means increasing demand for clean water and reduction of biocides in the environment.

- *Lowered use of industrial inputs (fertilizer, pesticides, etc).* Reduced agricultural chemical usage is needed to lessen adverse environmental impact and relieve demands on the fossil fuel supply.

To summarize, Harwood argues that "a sustainable agriculture must make optimal use of the resources available to it to produce an adequate supply of goods at reasonable cost; it must meet certain social expectations, and it must not overly expend irreplaceable production resources."

Madden (*in press*), who has written extensively on this subject, gives a slightly more restrictive definition: "The ideal or norm is characterized as a farming system in which an abundance of safe and nutritious food and fiber is produced using farming methods that are increasingly sustainable, profitable, and ecologically harmless." Madden doesn't specifically mention the social aspects of sustainability.

Liebhardt (1987), director of the University of California Agricultural Sustainability Program, is more succinct, noting that sustainable systems tend to minimize the use of external inputs and maximize internal inputs which already exist on the farm.

Given the heuristic nature of these definitions, it is understood why the paths to sustainable outcomes are not clearly marked. Douglas (1985), in a conference presentation entitled *Sustainability of What? For Whom?* notes that even our knowledge about the limits or break-points of overstressed natural support systems is very meager. Yet, further reflecting on the definitional imprecision of agricultural sustainability, Douglas asserts (laments?) that "it ought to be possible to construct a set of techniques, institutions, and public policies that move us toward outcomes that reflect consistent economic, ecological, and community goals." He concludes with an admonition that research scientists must at least try harder to anticipate and minimize the adverse consequences of potential new technologies and designs.

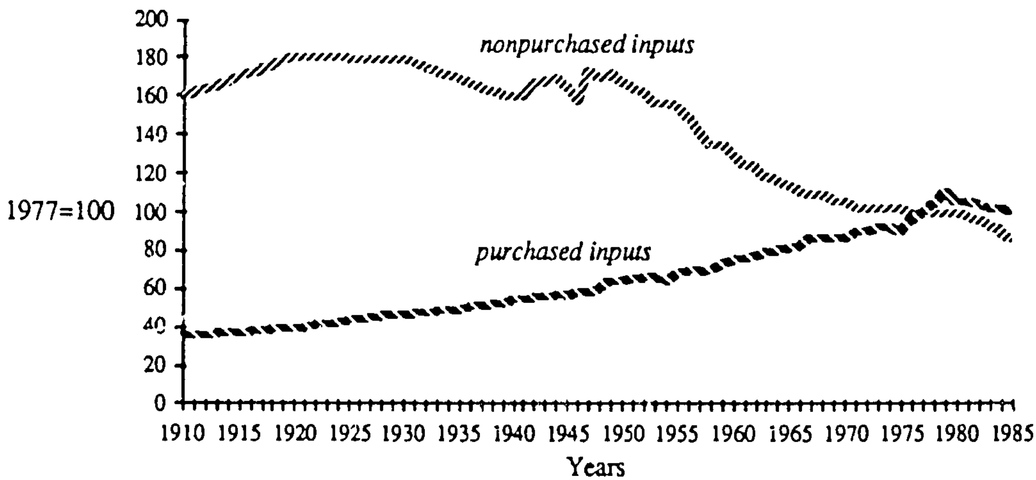
The Current Agricultural System

Perhaps before we assess alternative agricultural systems, we should briefly examine the record of the existing system. A succession of new technologies has helped transform societies over the last few centuries from predominantly rural to urban. The heavy plow was introduced in northern Europe along with the harness and nailed horseshoe, resulting in a doubling of agricultural productivity with horses over that with oxen (White, 1962). Mechanical power replaced the horse early in this century, resulting in further productivity gains and releasing vast amounts of land for food production that were formerly used to produce animal feed. Over the last half century, the revolution for the developed and, to a lesser extent, the developing world has been in terms of chemical technologies applied to agriculture. The productivity gains have been indeed impressive. The next technological revolution is expected to come from the "new" biotechnology, particularly recombinant DNA.

What are the trends in input use since the turn of the century? Figure 1 shows the dramatic downward trend in nonpurchased farm inputs (i.e., those produced on the farm) and the upward trend in purchased inputs (the fertilizers, pesticides, equipment, machinery, hired labor, etc.). Daberkow and Reichelderfer (1988) calculate that since 1900, total production expenses in the United States have grown from 45% to over 80% of gross farm income. Between 1950 and 1985, manufactured inputs, interest and capital related expenses as a share of total production cost almost doubled (from 22% to 42%), whereas labor and farm-origin input expenses declined from 52% to 34%. Similar trends are found in other developed regions and in the developing countries with the greatest productivity gains. Sustainable systems that tend to minimize the use of external inputs and maximize the internal inputs that already exist on the farm must find a way to reverse these near century-old trends.

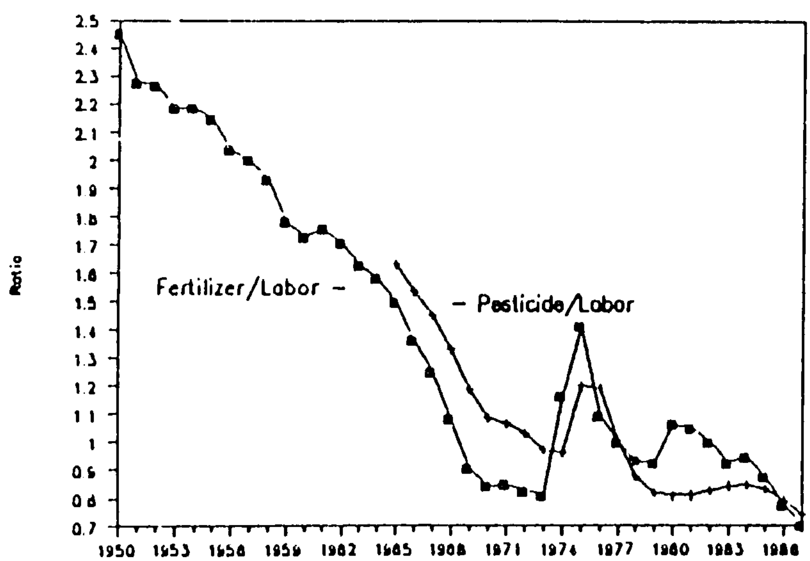
Relative prices are an important factor in farmers' decisions to shift to (or from) energy-intensive production. Daberkow and Reichelderfer (1988) explored price relationships between various chemicals and other substitute factors. During most of the last four decades, both farm wage rates and the price of farm machinery increased at a faster rate than farm chemicals (Figures 2 and 3). These data show that agrichemicals became relatively less expensive over time; fertilizer and pesticides became cheap substitutes for competitive factors and were attractive adjuncts to complementary factors. Thus, price incentives have contributed importantly to increased chemical usage in the postwar years; these high chemical application rates have been only slightly moderated recently, due in part to declining product prices.

Figure 1. Indices of farm purchased and nonpurchased inputs, United States, 1910-1985



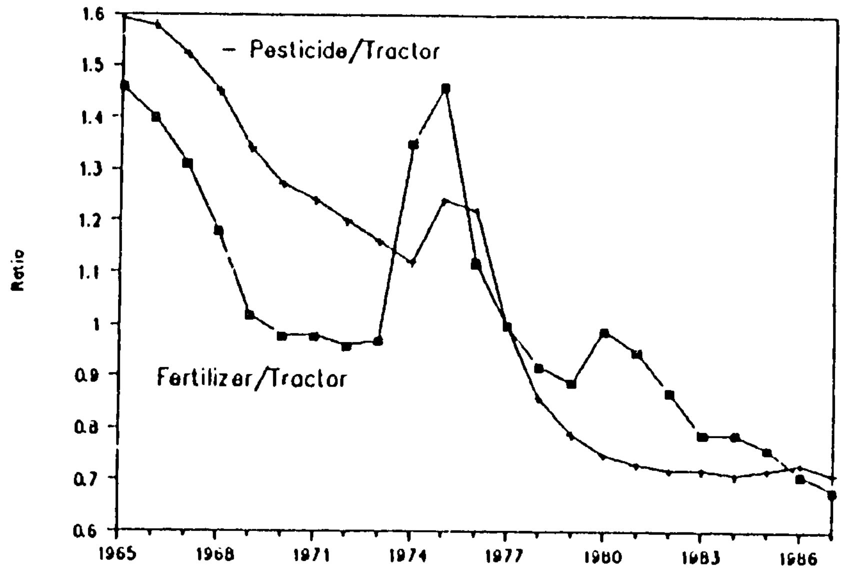
SOURCE: USDA (1986).

Figure 2. Ratios of fertilizer and pesticide price indices to the farm wage rate index in the United States, 1950-1986



SOURCE: Daberkow and Reichelderfer (1988).

Figure 3. Ratios of fertilizer and pesticide price indices to the tractor price index in the United States, 1950-1986



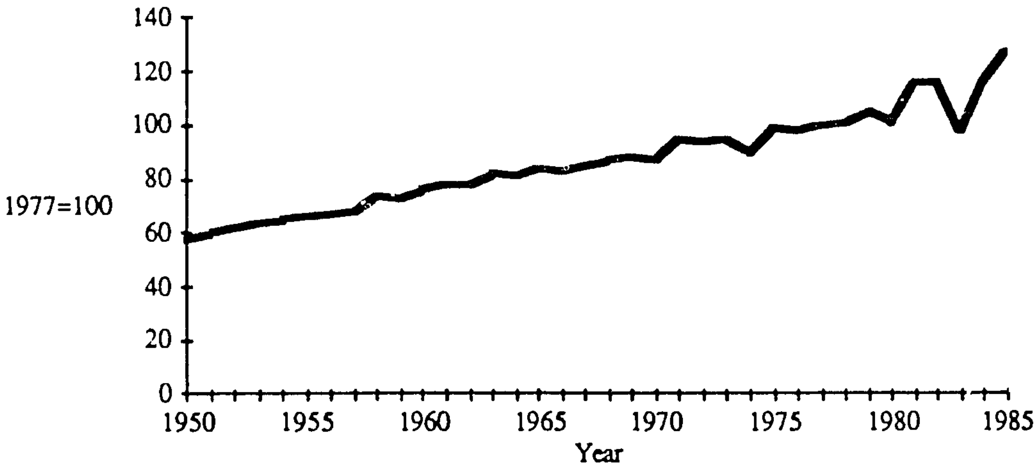
SOURCE: Daberkow and Reichelderfer (1988).

This conventional agricultural system that has relied heavily upon purchased inputs of fertilizer, pesticides, and other energy-intensive factors is considered a success story in terms of traditional measures of output and productivity (Figure 4). The food crises and regional famines that have occurred periodically throughout history have not been from lack of global agricultural production capacity. Better distribution of the abundance remains a key social and economic challenge.

This century began with a world population of around 1 billion. It is projected to end with close to 5 to 6 billion people. Yet, the Malthusian prophesy remains unfulfilled largely because of a succession of new technologies that have continually expanded the productive capacity of the global food and agricultural system.

Before the recent drought, U.S. overcapacity was about one-third of recent annual production of corn, wheat, and rice and about 10% of total annual dairy production (U.S. Council of Economic Advisors, 1987: 147-178). But, in contrast with earlier decades, the current overcapacity extends far beyond U.S. borders to most of the

Figure 4. Farm productivity: Index of output per unit of input, United States, 1950-1985



SOURCE: USDA (1986).

developed world. During the 1980s, world stocks of sugar have risen 45%; world butter stocks amount to about one-third of total annual consumption. World wheat stocks held by major exporters had increased by two-thirds between 1981-82 and the end of 1985-86. During this period, the U.S. share of world wheat stocks increased from 50% to 62%, the equivalent of two years of domestic consumption. At the end of 1986-87, it is estimated that the United States held about three-quarters of the world stocks of coarse grains, which represents about one year's domestic consumption. Admittedly, the growth in stocks reflects in part the policy choices made by developed nations to protect their farmers from the realities of the world market; yet they also attest to the productivity success of the conventional agricultural system.

And the current abundance is not a phenomenon seen only in the developed countries but in parts of the underdeveloped world as well. Avery (1988) shows that many developing countries are participating in the global expansion of agricultural output. He cites the dramatic turnabouts in India, China, Bangladesh, and Indonesia that defied some "experts." India, for example, was characterized two decades ago as a hopeless "basket case" by the Paddock brothers (1967) in their book, *Famine-1975!* In the 1980s, India has sold wheat surpluses abroad. Only very recently – since the late 1970s – China has made a great agricultural leap forward and now competes with U.S. farmers on cotton and grain export markets. Similarly, Brazilian soybeans and Argentine grain are now marketed internationally. The Green Revolution that has so

Table 1. Growth rates for agricultural production

Region[1]	Growth rates (percent per year)			
	1951-60	1961-70	1971-80	1980-84
Developed countries	2.5	1.9	1.8	1.1
Developing countries	3.1	2.7	3.2	3.0
Latin America	3.3	2.7	3.5	0.0
Mexico	5.3	4.0	2.8	−1.0
Brazil	5.1	2.7	4.4	1.7
Argentina	2.0	2.1	4.4	0.5
Middle East	4.2	3.0	3.8	−0.6
South Asia	3.3	2.5	1.8	1.5
India	3.4	2.1	2.4	2.4
Southeast Asia	2.8	4.2	4.6	2.3
East Asia	5.1	4.4	4.7	−0.2
Indonesia	2.9	1.7	4.2	4.2
People's Republic of China	1.7	2.0	1.9	5.2
Africa[2]	2.9	3.0	1.1	1.6
Sub-Saharan Africa[2]	3.1	2.2	1.5	1.7

SOURCE: USDA (1981 and 1985).
1. Country groupings are as defined by the U.S. Department of Agriculture.
2. Excluding South Africa.

greatly increased the world's grain supply, and applications of biotechnology to plant and animal agriculture, promise more.

On an aggregate basis, worldwide, there has been an upward trend in food production, both on an absolute and a per capita basis. Total food production doubled between 1950 and 1984, yielding a yearly compound growth rate of about 2.6%. Perhaps it is more revealing and of some concern to view food production growth rates incrementally over time (Table 1). In the developed regions, growth rates each succeeding decade have been falling consistently since 1950. The developing countries show considerable variability over time with an overall long-term rate close to 3%. The aggregate performance of the developing countries, however, is enhanced by the strong growth in a few large regions – the People's Republic of China, India, and

Indonesia. Meanwhile, growth rates in Latin America, the Middle East, and elsewhere in the developing world have dropped markedly. Given these declining growth rates in the developed and much of the developing world, a closer examination of the current intensive system of production in terms of long-term success in meeting needs may be required.

What Is the Impetus to Change Our Current System?

Thus, despite the impressive picture painted of productivity gains under the current agricultural system and the hopes for continued or even expanded growth as expressed by Avery (1988) and others, the rate of increase in food productivity has been diminishing (Table 1). Does this portend some approaching capacity limits to productivity gains from high-tech agriculture? What other concerns about conventional production technologies in farming for developed and developing countries are being raised? A list includes the following:

Groundwater contamination. Groundwater contamination occurs from the leaching of agricultural chemicals and by-products into the underground aquifers used as a source for drinking water. In the United States, residues of 17 different pesticides have been detected in groundwater in 23 states (EPA, 1985). About one-third of all U.S. counties are vulnerable to groundwater contamination by pesticides (Nielsen and Lee, 1987). Some data indicate pesticides in the drinking water of over one-fourth of the people in Iowa (Crosson and Ostrov, 1988: 13-16). California's Proposition 65, the Safe Water and Toxic Enforcement Act of 1986, holds industries, including agriculture, directly accountable for their use of chemicals that can cause cancer, birth defects, and sterility.

Food safety – Pesticide residues on agricultural commodities. A number of recent consumer attitude surveys have revealed that pesticide residues are judged to be a serious hazard to health (Food Marketing Institute, 1987: 32). In fact, many consumers tend to be more worried about pesticides than about hazards that food safety experts feel are much more serious (e.g., fats and cholesterol, microorganisms) (York, 1987). There has recently been a spate of publications on the subject, attesting to – or raising – the concerns of U.S. consumers. Among them: *Leaching Fields* (California Assembly Office of Research, 1985), *Regulating Pesticides in Food: The Delaney Paradox* (National Research Council, 1987), *Pesticide Alert* (Mott and Snyder, 1988), and *The Invisible Diet* (Price, 1988). The University of California Agricultural Issues Center sponsored a year-long study looking at all the ways various agricultural chemicals find their way into our food supply, what the risks are, and what should be done about it.

The health and safety of farm workers. There is more definitive knowledge about pesticide-related illness among farm workers. Many argue that worker safety is of a higher priority than food safety in reference to agricultural chemical usage. Quoting Donald Kennedy (1988), president of Stanford University: "a careful look at the problems of occupational health and problems of consumer health reveals that they are not the same. Persistence is an important feature of pesticide risk to consumers; but the occupational threats to production workers, applicators and agricultural field workers relate much more to immediate toxicity. Thus the organophosphate insecticides, if proper reentry times are not observed, constitute major occupational hazards – but owing to their rather quick degradation they are not the major problems for consumers." In California in 1986, 1,065 cases of pesticide-related occupational illness were confirmed by the state – nearly all were among agricultural workers (Stimmann, 1988).

Wildlife and natural species endangerment. Environmental contamination from agricultural chemicals has in some areas caused direct harm to certain wildlife species and indirectly affected others that prey on those who tend to accumulate residues in their tissue. Cacek (1985, as cited by Crosson and Ostrov, 1988) ties the estimated 40% to 80% decrease in wildlife population in the midwestern states from the mid-1950s to the mid-1970s in a large part to the increased use of agricultural chemicals. Legislation specially restricting agricultural chemical use in known habitats of endangered species has been enacted.

Increasing costs of production to farmers. The severe recession experienced by farmers in the first half of the 1980s has accentuated the need for cost-reducing technologies which provide less reliance on purchased farm inputs. For example, in California, costs of pesticide purchases and applications for speciality crops may be as much as 20% of total direct costs for a season. One California grower (Sills, 1988: 100) who has turned to organic farming reports: "it appeared to me that we were spending a lot of money to produce crops that were in over-supply, and using a great deal of high-priced chemicals to do so. In rice and almond weed control, it seemed that I was selecting for the weed that was hardest to kill, and invariably that last weed required the highest-priced herbicide to control it." Pest resistance to chemicals that have worked well in the past is an increasingly serious problem.

The U.S. Congress created and funded a new research and education program as part of the 1985 Food Security Act. Known as Low Input/Sustainable Agriculture (LISA), this program funds research and education activities that are intended to improve profitability of low-input farming alternatives.

Dwindling supplies of important resources. An energy crisis in the early 1970s and books and reports in the vein of *Limits of Growth* (Meadows et al., 1972) drew attention to the scarcity and capacity limits of important nonrenewable resources and their relationship to population growth and affluence. Lester R. Brown (1988) writes in *The Vulnerability of Oil-Based Farming* that "Agriculture is over the barrel. . . . The world-wide practice of boosting crop output by using more energy-intensive inputs will make agriculture more dependent on oil at a time when oil supplies are diminishing."

Recently, in the face of mounting commodity surpluses, U.S. farm legislation has taken a conservation posture. The 1985 Food and Security Act included provisions for a conservation reserve program, a conservation compliance requirement, and sodbuster and swampbuster programs; all aimed primarily at reducing soil erosion. The World Bank is also bringing environmental concerns to the center of its policy-making agenda with the creation of a new Environmental Department overseen by the vice-president of policy, planning, and research (AAAS, 1988). President Barber Conable said in his reorganization speech that "sound ecology is good economics."

What Do We Know about Sustainable or Low-Input Systems?

What do we know about alternative systems -- ones that meet some criteria of sustainability or "regeneration"? Are alternative production systems ready for adoption in both developed and developing countries? The short answer is that the number of experimentally designed, empirically replicated studies on sustainable or low-input farming systems is very limited, compared to those on conventional methods. Ten years ago information was almost nonexistent.

The last few years show increasing evidence of research and extension activity dealing with various aspects of low-input systems in most every agricultural research institution (Madden, *in press*; Liebhardt, 1987; Poincelot, 1986; Reichelderfer, 1987). Many are comparative analyses, some using replicated experiments, whole farms, and side-by-side field comparisons. Farming practices in the eastern and midwestern United States have received the greatest attention nationally, with relatively little work done for specialty crops in the irrigated western states. An important point is that requirements for any farming system, including low-input, vary between countries, between regions, and even from farm to farm. Thus, much of the research so far on alternative farming systems is based on case studies that are only suggestive of possible outcomes but difficult to generalize.

Madden (*in press*) indicates that surveys of farmers and visits to farms where various low-input farming methods are used have provided insights regarding the profitability and potential for widespread adoption of these methods. Madden also stresses the need to consider the adoption of low-input techniques on a long-term basis to realize the full benefits. The complexity of tailoring a system to unique on-farm conditions requires time and considerable management skill.

Some of the alternative, low-input methods being analyzed include the use of natural enemies or biological control agents; appropriate field selection; changes in land preparation, irrigation, tillage, and sanitation practices; improved timing of planting; and choosing resistant varieties. Attempts are made to substitute renewable sources of soil nutrients such as manures and legumes for chemical fertilizers, partially or in total. Any of these changes must be considered in the context of the entire farming system. Case studies show that, under particular conditions, low-input systems can result in economic returns close or equal to what can be realized with conventional farming methods. In most cases, the farmer is substituting land, labor, and especially, management, for chemical inputs. The extra management/experience is emphasized by Madden (*in press*) who claims that if farmers choose (or are forced by regulatory or other pressures) to switch abruptly from chemical-intensive to certain kinds of low-input farming methods, initially their yields would probably decline sharply.

Studies of low-input methods often emphasize the cost/benefits of adopting a particular farming method as it relates to the enterprise (e.g., rotation effects on corn yield). Yet, proponents of sustainable systems contend that the effective "system" boundary usually includes the entire farm or management unit, its crop and animal mix, the crop rotation or sequence and the flow of materials through the system over time. Liebhardt (1986) points out that a systems analysis is required and that analysis must involve not only the inputs and outputs of the agricultural process, but the environment at large (physical, economic, institutional) and the interaction among these many components. Few studies are yet available that address such complex interrelationships on the whole farm for low-input practices.

Integrated pest management

Integrated pest management (IPM) is an approach that has achieved notable success in numerous regions and with a variety of crops – and falls within the rubric of low-input agriculture. The strategy is to use a combination of biological, physical, and chemical controls, habitat modification techniques, and "whatever works" to economically reduce pest damage and minimize chemical use. Programs have been developed for corn, cotton, alfalfa, soybeans, grapes, apples, almonds, peanuts, and tobacco, to mention a few. In many cases, farmers are able to reduce and sometimes eliminate pesticide applications that would be routinely used under conventional systems. And what is most important for widespread adoption, IPM practices are usually profitable, particularly when properly applied to cropping systems and regions where high rates of pesticides are normally used. As with other low-input practices, IPM calls for careful multidisciplinary analysis at the research level and more sophisticated and skilled management and more information at the farm level than is required for conventional or traditional farming.

A systems approach to research on alternative agriculture

Most proponents of low-input systems argue for orienting at least part of the research and extension activities around multidisciplinary teams who use a "systems approach." The whole-farm (and its environment) analysis requires the joint efforts of researchers and extension specialists in, for example, agronomy, soil and water sciences, entomology, animal science, engineering, and agricultural economics.

Table 2 illustrates the many factors – genetic, environmental, agronomic, and economic – which determine the specific types and amounts of pesticides needed for a particular crop, in a particular field, in a particular season. A multidisciplinary team effort and much individual consultation with users are required. Since most agricultural universities are organized around disciplinary departments and incentives within these departments are related mostly to individually published results within a specialty, considerable reorganization may be needed to mount a serious research/extension effort to understand and apply low-input agricultural systems.

Table 2. Factors influencing changes in pesticide use

Genetic	Environmental	Agronomic	Economic/Policy
Crop species	Location	Cropping pattern	Management system on farm
Variety	Climate	Planting date	Consumer demand/ market structure
Pest resistance	Year-to-year changes	Irrigation methods	Relative costs of control practices
Chemical resistance	Soil	Field selection	Regulations and farm programs
	Water	Tillage	Farmers beliefs and attitudes
	Pest populations and inoculum levels		
	Beneficial organisms		

SOURCE: Liebhardt (1988).

This is not to imply that all low-input methods and options require only applied research. The search for effective reduced chemical alternatives will require the full spectrum from basic to applied research. For example, developing strategies for using biotechnology against pests requires much basic research before application is even considered. Products from biotechnology approaching the marketing stage in two to seven years are improved microbial insecticides, pest-resistant transgenic plants, herbicide-resistant transgenic plants, insecticide-resistant transgenic parasites/predators, transgenic bacteria, and production of natural antibiotic/antiviral agents by animals, plants, and bacteria (Hayenga, 1988).

Macro-effects of low-input systems: Research needed

While most attention has centered on the feasibility of low-input systems at the farm level, questions about the larger impacts on the economy (macro-effects) from widespread adoption of low-input technologies have been largely ignored by serious researchers. There is only one major study known to me. Langley et al. (1983) estimated aggregate supply and aggregate income effects for alternative scenarios comparing organic farming to conventional farming. Under the assumption that all farms would switch to organic methods, overall supply of soybeans, wheat, cotton, and feed grains would decrease, but the area farmed would increase. The value of production under the organic scenario would increase dramatically for all crops but soybeans, due to the restricted supply and an assumed inelastic demand. Higher costs of production would result due to inclusion of marginal lands in the production process, but net farm income would increase due to the higher value of production. The reduced supply under the organic scenario would mean a decrease of more than 50% in the level of exports below that in the conventional production scenario.

Numerous questions have been raised about the methods, assumptions, and data used in this study. Quite obviously, at this stage, so little is known about expected yields and costs for low-input systems for most U.S. cropping situations and the associated price effects, that its results must be viewed with caution. For one thing, new (even profitable) technologies are never adopted overnight, but require a considerable transition period. Therefore, more gradual adjustments in prices and resource use would be associated with any move toward low-input farming. So there is yet little guidance other than speculation about the important macro-effects (e.g., farm income, exports, consumer food prices, and the structure of the agricultural sector) of a switch in farming systems toward a low-input farming system.

Impediments to Change

Cochrane (1979) discusses how an entire technological strategy was forged for American agriculture based on cheap energy inputs (fuel, fertilizer, and pesticides) over the period 1920-70. The energy situation changed in the early 1970s, but investments (both in people and machines) consistent with cheap energy prices remain largely in place.

The farming structure that has evolved helps explain farmers' reluctance to adopt low-input or sustainable systems. For example, U.S. farms, as well as their counterparts in other developed countries, tend to be highly specialized. But multiple cropping systems and even multiple crop-livestock systems are the hallmark of most low-input systems. The fixity of the heavy investment in equipment and machinery (and debt load) of existing farms operating with conventional practices means that a formidable disinvestment would be involved in a switch to alternative farming systems. Also, most farm managers and much of the farm work force are trained for conventional agricultural system technologies; retraining has its costs and requires time.

Government programs that provide incentives for high-input farming were devised in an era of cheap energy and remain largely intact. The food processing and distribution system has evolved to complement the current production system and to meet the needs of masses of people in metropolitan areas. For example, the premium put on fruits and vegetables that are cosmetically appealing to consumers makes it difficult to produce and market profitably without chemicals.

Farming conditions and practices in a peasant agriculture would suggest an easy transition to low-input systems (Altieri and Anderson, 1986). Here, greater reliance is placed on family labor, integrated crop-livestock operations, and polyculture -- all components of "sustainable" systems. Moreover, farmers in many developing regions are located on small holdings of marginal land with limited access to capital, credit, and markets, prerequisites for conventional agricultural operations. Yet, Reichelderfer (1987) observes that the trend is towards more, rather than less, use of agricultural chemicals in the developing world. Fertilizer application rates are up, with the largest gains in Asia whose rates doubled between 1974-76 and 1981-83; the value of pesticide imports to Asia more than tripled in constant dollars between 1971-73 and 1983-85. Apparently, in peasant farming areas using low-input practices that have evolved over generations, the pressure to boost food productivity via Green Revolution technologies and turn a profit means a shift toward the chemically intensive practices of the developed world.

An Agenda for Change

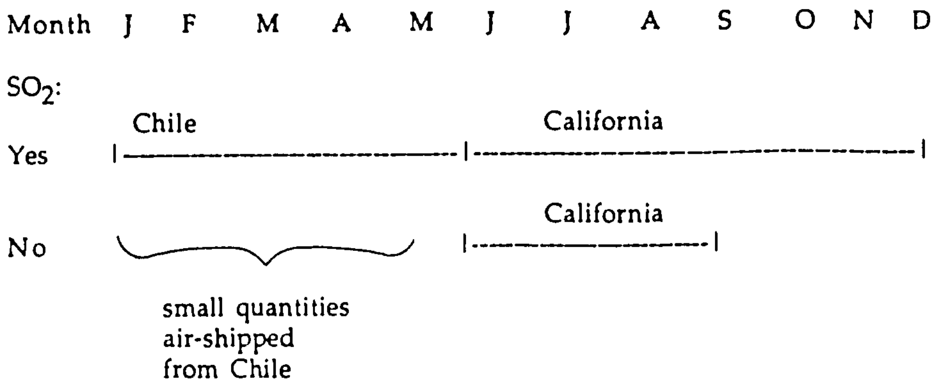
In conclusion, I make two observations. First, I would argue that our area of inquiry for considering change should be broader than the farm production system that has received so much emphasis. It is society and the people within it that we want to sustain over time. As important as the agricultural production system is to that goal, it should not be considered as an end in itself or independent of other aspects that come together to define quality of living in its broadest sense. It makes little sense to make decisions at the production level affecting the quality of the product if that product cannot be profitably marketed because of constraints in another part of the food chain. As agriculturalists, we must give primary attention to the total food system – production, processing, and distribution. That is, we want to consider changes in the total food system (and not just production) that can meet the growth in food demand and be consistent with societal long-run food safety and environmental goals.

Second, chemical use and any alternatives to chemical use at whatever level of the food system must be viewed and analyzed in a benefit/cost framework (even though some currently emphasize only the cost side, ignoring the benefits). And these costs and benefits are not only those to the farmers using chemicals, but to consumers and society as a whole.

Antle and Capalbo (1986) write of the benefits and costs to farmers and other food system participants and to society. Benefits to farmers from use of agricultural chemicals include increased yields and reduced pest damage; costs are the additional outlays for the chemicals and possible hazards in applying them. Similarly, benefits and costs can be calculated for whatever chemicals or additives are used at various levels of the food chain, including processors, wholesalers, and food retailers. Quantification of these costs/benefits for conventional practices is usually possible because of their impact through the marketplace; calculation of costs and benefits for low-input systems not yet in full operation is much more difficult.

Consumer benefits of chemical use within the food system include possibly increased quality and quantity of food and lower prices and increased availability of perishable foods over longer periods. Consider the health benefits of having a year-round supply of fruits and vegetables available in many parts of the world. Were SO_2 use eliminated from postharvest grape handling, the U.S. availability would shrink from year-round to just over two months (Figure 5). Costs to society may include consumer health risks from residues on crops, exposure of farm workers to contaminants, degradation of underground aquifers and waterways. Quantification of these effects is difficult since both market and nonmarket evaluations are involved.

Figure 5. Availability of table grapes in United States markets with and without SO_2 fumigation



SOURCE: Kader (1988).

Further, we need to understand what policies are appropriate when social benefits do not exceed or equal social costs. The impacts of any regulation usually extend far beyond its intended purpose. And conflicting regulations currently plague the food industry in the United States.

Increasingly, signals are being heard that our high-technology, energy-intensive agricultural system has not only *not* sustained agricultural and food productivity, but it is causing troublesome environmental problems and exerting pressure on the resource base. These concerns have not been translated into quick action and change. Legislation in the United States has been passed at the state and federal level aimed mainly at some of the environmental issues. Many farmers do express interest in changing to low-input practices, but so far they have not done so on a very widespread basis, for a variety of reasons – lack of knowledge, risk of decreased profits, or fixity in existing investments. Farmers can't be expected to bear all the costs when they can claim only a share of the perceived environmental benefits.

Agricultural academic institutions are allocating only a small percentage of their budgets to sustainability or low-input research projects but this is several-fold more than it was even five years ago. Biotechnology is the current "favorite" in many land-grant institutions and is taking a lion's share of the budget. The U.S. Department of Agriculture is funding a relatively small program of research and education on low-input sustainable agriculture but this is infinitely more than it has been in the past. My impression is that the level of activity is similar in other countries.

In summary, we have considerable interest – even deep concern by some groups – but no groundswell of support for abrupt action or change. Nor do we have sufficient information on the farm, regional, or global impact of such a change. The current agricultural system evolved over considerable time, and with some "nudging and pulling" we can in time tilt it in a different trajectory. As Douglas (1985) stated earlier – as research scientists, we must try harder to anticipate and minimize the adverse consequences of potential new technologies and designs. The general public must continue to articulate its concerns and our representatives in government must respond to them.

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Conservation and Management of the Environment and Natural Resources in Developing Countries – Policy Implications for ACP States

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Introduction

The relatively short history of international agricultural research has been characterized by a number of slogans, catchwords, and phrases during different phases: *green revolution*, *resource-poor farmer*, and recently, the discussions are dominate by the term *sustainability*. All these terms were introduced by politicians, administrators, or other so-called decision makers, rather than scientists. The catchwords have advantages and disadvantages. One advantage is that such terms draw attention to urgent problems which may have been overlooked or neglected, and are now being given high priority in outlining agricultural policies, and formulating research and development projects.

The term *green revolution*, coined approximately two decades ago, made clear that the introduction of high-yielding varieties of wheat and rice was not the only factor for increased production of these two crops, but that a completely new agricultural technology with high inputs of fertilizer, pesticides, and water was required to bring to fruition the research activities of the International Maize and Wheat Improvement Center (CIMMYT) and the International Rice Research Institute (IRRI). However, during the first years of the green revolution, a structural change detrimental to resource-poor farmers, especially in India, took place. Donor countries and donor agencies became aware of this problem and insisted that special attention should be given to problems of the resource-poor farmer in outlining and implementing research projects. Later on, farming systems research was another attempt to analyze and understand the problems of a farm in its broad context, and to identify research projects using this holistic approach.

The disadvantage of utilizing catch phrases is that research managers may take an opportunistic attitude only to obtain the necessary funds to match the requirements of the slogans. They may design research programmes in a manner similar to the couturiers in Paris or Milano who design ladies' fashion for each season according to the taste and *zeitgeist* of rich international society. Such an attitude is reflected by statements in the minutes of the report of the Consultative Group on International Agricultural Research (CGIAR) on the 1988 Mid-Term Meeting, which says that to provide agricultural technology which could secure sustainability, "increased flows of assistance would undoubtedly be sought as this process got under way" (CGIAR, 1988).

However, the term *sustainability* is not only useful but essential. Definitions of sustainability in standard reference books are inadequate, and in the context of our considerations are not very helpful. Only in specific recent publications is the problem of sustainability dealt with more comprehensively with a more precise definition.

The Brundtland report (World Commission on Environment and Development, 1987) explained sustainability:

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

It contains two key concepts:

1. *needs* (in particular the essential needs of the world's poor) which should receive overriding priority;

2. the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

TAC's (1987) definition is that:

> Sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources.

The Concern about Sustainability

The responsible farmer has always returned to the soil what the crops removed from it, either in the form of manure, inorganic fertilizers, or both. Even the resource-poor farmer practising shifting cultivation has practised, knowingly or unknowingly, a farming system on a sustained basis for hundreds of years.

However, during the last decades considerable changes have taken place. Most developing countries have experienced a rapid population increase. As a result, the pressure on the land has increased at a rate never before known. Millions of hectares of tropical forests have been cleared for food production, in most cases without consideration for ecologically sound agricultural practises after deforestation. The results are frightening: land degradation, erosion, silting of rivers and lakes, to name only a few. The stocking rate of animal populations has been augmented at a rate which in many countries exceeds the carrying capacity of the land. Shifting cultivation, which does not allow the soil to recover after its exploitation, is taking place at an ever-increasing rate due to land shortages.

As a result of these calamities, economists, administrators, and scientists recall the theories of Robert Malthus, who at the end of the 18th century, concluded that the human population has a tendency to increase geometrically, whereas agricultural production increases in an arithmetical progression. However, this theory appears to be incorrect.

Fortunately, because of scientific advances and technological progress, especially in the biological sciences during the last two centuries, the theories of Malthus have been proved wrong, at least in Europe, North America, and even other parts of the world. In Europe, governments are confronted with the problem of surplus production.

However, the present surplus production in Europe or North America should by no means be taken as an indication that food production will attain similar levels in tropical countries. On a global basis, the most serious problem during the next century will be to feed people without destroying our natural resources. In other words, to implement systems of sustained agriculture. It is not by chance that the environmental and food crises have received increasing attention from international organizations, national governments, political parties, and society as a whole during the last few decades.

As early as the 1950s, the Paley Commission in the USA expressed concern about the use and abuse of natural resources. During the 1960s, the Club of Rome played an influential role in announcing the so-called "Limits of Growth." Early in the 1970s, under the auspices of the United Nations, the Stockholm Conference on Human Environment took place, subsequently leading to the establishment of the United Nations Environmental Programme (UNEP). And the 1974 World Food Conference in Rome resulted in the establishment of the International Fund for Agricultural Development (IFAD). In 1980, in collaboration with the International Union for the Conservation of Nature, the World Wildlife Fund, FAO, and UNESCO, UNEP submitted a paper entitled "The World Strategy for Conservation." FAO also submitted a study in 1980 under the title "Agriculture 2000."

The last decades witnessed a series of international conferences dealing with problems of environment and sustainability such as desertification, housing, water, energy, and deforestation. More recently, in 1983 the United Nations established a special commission "to propose long-term environmental strategies for achieving sustainable development to the year 2000 and beyond." The report of the World Commission on Environment and Development (1987), *Our Common Future* (also known as the Brundtland Report, named after the commission president, Norwegian Prime Minister Mrs. Gro Harlem Brundtland), came out in 1987.

On the other hand, for a long time the World Bank expressed only limited interest in environmental problems and gave priority to projects aimed at increased production. Responding to criticism, the World Bank now considers environmental problems a high priority.

Also very late, the CGIAR took note of the problem of harmonizing food production for a rapidly increasing population while maintaining and even improving natural resources, especially soil and water. By the end of 1986, a special subcommittee of the Technical Advisory Committee (TAC) of the CGIAR was created to address the problem of sustainability in the research activities of the international agricultural research centres (IARCs). In March 1988, TAC submitted a first paper on this issue. Two research organizations, the International Board for Soil Research and Management (IBSRAM) and the International Irrigation Management Institute (IIMI), may finally be incorporated into the CGIAR system. With this step, the CGIAR will end the stagnation resulting from its philosophy of concentrating only on yield increases of important crops and creating green revolutions, and embark on a new phase of research activities.

Sustainability: The Physical Factors of Climate and Soils

Africa

Among all the factors that influence agricultural production, climate and soils are the most important. This is most dramatic in Africa, where the high temperatures and high humidity of equatorial Africa provide ideal conditions for pests and diseases. This includes livestock diseases such as trypanosomiasis, which has a profound effect on the whole pattern of agriculture in Africa. An area of around 10 million km^2, or about half the nondesert area of Agrica, is affected by this disease; all domestic livestock, even sheep and goats, are at very high risk. The integration of livestock into farming and the use of animals for labor is virtually impossible in these areas.

Outside the equatorial belt lie the arid and desert regions. The Sahel region in the north has had its share of notorious publicity and is now fairly well known by all. What is less familiar is the southern arid region which includes Botswana, Zambia, and Mozambique, where agricultural production is severely depressed in most years.

Africa's rains are torrential and more destructive to the soils than the gentler rains of temperate zones. Water run-off carries off fertile soil, and if ploughing and planting are not carefully timed, weeds can depress yields. A particularly despairing feature is the unpredictability of rain in Africa, from year to year as well as within seasons. From what we have recently witnessed in Africa, it appears that the less rain an area gets, the greater its variability. In this respect, the drought this year in the USA has led scientists to assume that desertification of the whole planet has already started. However, we should be cautious about taking annual or periodic fluctuations as irreversible trends.

The soils in Africa are no less crucial than the climate. Acid tropical soils, Oxisols and Ultisols with pH values lower than 5, cover the largest area of Africa, approximately 470 million ha, or 27% of the continent, in Central, Southern, and West Africa. Until recently, most acid soils were covered with forests, which are now increasingly being cleared to open new lands for agriculture. The management of these newly cleared lands requires special technologies to ensure sustained production. However, only limited experience in this respect is available (IBSRAM, 1988). The deforestation in Africa is estimated at 11 million ha per year (UNEP, 1984), and because these technologies are either unavailable or are not used, approximately 6 million ha are reduced to desert-like conditions each year.

The heavy rains in Africa leach nutrients and degrade the soils. The high temperatures rapidly break down organic matter and inhibit nitrogen fixation by rhizobacteria. All these factors tend to produce soils that are among the least fertile in the world. Wind erosion does much damage in the dry areas.

Exports of agricultural products are the main foreign exchange earner for African countries, especially the least developed. With increasing populations and decreasing prices for primary commodities, these countries face enormous economic pressures to overexploit their environmental resource base.

Caribbean and Pacific islands

As in Africa, the main base of the economy of the Caribbean and Pacific island countries is agriculture. Agriculture, including forestry, generates over 70% of the gross national product of the majority of the African, Caribbean, and Pacific (ACP) states. In the Caribbean and Pacific islands, agriculture (including forests and fisheries) also provides food, fuel, and raw materials for processing, building, and other domestic uses. Now almost all the islands are dependent on imported food, partly for historical reasons, partly because they have outgrown their resource base.

Moreover, shifting cultivation is becoming more and more difficult with the pressure of population growth. The flatter lands of the volcanic islands are relatively fertile, whereas others such as the atoll islands of the Pacific region, e.g., Kiribati and Tuvalu, are mere deposits of rubble, arid sand with some rock, and hard pan. Soil development is poor and agricultural potential limited.

Sustainability: Research Implications

When the first international agricultural research centres were created some 20 to 25 years ago, only the need for rapid increases in production was considered. The fathers of the CGIAR were anxious to increase agricultural production in developing countries at any rate. As a result, they saw the best chances to reach this goal by concentrating agricultural research on crops with a high potential in regions with good soils, adequate water, and a workable infrastructure to procure inputs such as fertilizers and pesticides. The results of this research policy were impressive.

According to statistical data prepared by the CGIAR centres, cereal production is at present 50 million tons higher each year, which corresponds to the annual consumption of approximately 500 million people, and this is due to the introduction of high-yielding varieties. A rough calculation reveals that these research projects can be considered as having the highest cost-benefit ratios. Assuming an average price of US$ 150 per ton, 50 million tons corresponds to US$ 7.5 billion per year, whereas the total expenditures for CIMMYT and IRRI over the first two decades may have been US$ 700-800 million. Even if the additional costs for fertilizer, pesticides, water, salaries, etc., are deducted, the results for farmers are outstanding. If the secondary and tertiary benefits are taken into the economic calculations, the value is even higher.

However, there are certainly a number of disadvantages connected with this success story. First, as a result of this research policy, less-favoured regions have up to now benefited only to a limited degree from the green revolution. This is the case for nearly all ACP countries, which face the greatest constraints because of poor soils and weak infrastructure.

Moreover, although yields have increased substantially, maintaining the high yield level is becoming more and more difficult, in spite of continued high inputs and the growing managerial skills of farmers (TAC, 1987). As a result of the introduction of high-yielding varieties of cereals, monoculture production systems have emerged, very often replacing legume crops. Furthermore, experience shows that for technical, infrastructural, and socioeconomic reasons, certain modern agricultural technologies may not be applicable to all parts of Africa or to all ACP countries.

From these experiences and observations, some general principles for research priorities can be summarized:

More attention to special situations. International agriculture must give more attention to regions with special constraints due to extreme climatic conditions, poor soils, weak infrastructure, and high population pressure, which among other problems, leads to indiscriminate forest clearing for food production, followed by desertification.

Food crops. Food crops other than wheat and rice which also improve the soil should be given higher priority. Improved cultivars of cassava, cowpeas, and potatoes are already available, but need to be introduced more widely through national agricultural research systems (NARS). Research on other crops that improve the soil is being conducted, but these activities should be intensified. Research on other traditional crops should also be pursued.

Soils research. Research on soil conservation, maintenance, and improved soil fertility has to be strengthened, even at the cost of crop research. The development of appropriate agricultural technologies to be used after forest clearing is of the highest priority, and land-use patterns for agroforestry have to be developed.

Fertilizers. Optimal utilization of manures and inorganic fertilizers is of great significance both for sustainable agricultural systems as well as for meeting the needs of small farmers and regions with special constraints.

Trypanosomiasis research. Research on this livestock disease is required for sustainable agricultural production systems, especially to introduce animal traction in specific regions of Africa.

Water use. Optimal water utilization for both irrigated and rainfed agriculture is an important factor for sustainable agriculture, and needs a higher priority from both IARCs and NARS.

Breeding for resistance. In view of the damage to the environment caused by pesticides, as well as their high cost, breeding for resistance should be given more attention, even to the detriment of yield. Conservation of plant and animal genetic resources is fundamental for sustained agricultural production.

On-farm research. Socioeconomic and on-farm research of farming systems or technologies, especially for ACP countries, is required for studies of sustainability.

Some of these research priorities have been dealt with in the TAC paper on research priorities (TAC, 1985). Others should be considered in a new context as a result of the introduction into the CGIAR systems and NARS of new research policies for sustained agriculture.

Sustainability: Organizational Aspects for Research

Approximately 25 years ago, when the first IARC was founded, it was assumend that research centres concentrating on a few crops would achieve good results in short time periods. The success of the green revolution proved this strategy. However, research aiming for sustainable agriculture is complex and difficult because it must be more location specific.

These considerations have implications for the future organization of international agricultural research. Because of the more complex and location-specific problems, IARCs may have to relocate more research from the centres to different locations.

Such a recommendation is also included in the TAG priority paper. Furthermore, much more research will be needed where the farmer is not an object of research, but rather an active participant. If farmers are actively involved in research projects for sustained agriculture, expensive experiments without much probability for success can be avoided.
To introduce research on sustained agriculture, NARS are indispensable. As a result, IARCs have to cooperate and collaborate much more intensively with NARS. New forms of cooperation, including financial support from the IARCs to NARS may be required. Research with very specific objectives, planned and evaluated on a standadized basis, and executed in different locations through networks, may be of special value in organizing activities for sustained agriculture. Such networks are already operated by IBSRAM, IIMI, ILCA (International Livestock Centre for Agrica), ICRAF (International Council for research on Agroforestry), and other centres. NARS cooperating in these networks are obtaining not only logistic and scientific support, but also some funds for relevant research projects. It may be useful to study the advantages of such relationships in more detail, both from the aspect of research results and with a view to strengthe NARS.

Sustainability: Agricultural Policies

The facts of life are sometimes different from theoretical discussions and the recommendations that come out of international conferences. People struggling for survival will not and cannot care about long-term sustainability if they will destroy even their long-term basis for survival. Politicians, administrators, and scientists should be careful not to blame the resource-poor farmer for this attidue and refrain from being arrogant. One resource analyst recently cited in a professional magazine said that "in India a great deal of painstaking and patient work will have to be done to wipe out the backlog of ignorance, inertia and complacency." It is not the ignorance of the farmers, it is not the farmers who are to be blamed, but society as a whole, if agricultural production is carried out, not on a susstainable basis but by mining or *raubbau* (plundering).

Agricultural policy must provide a framework that allows farmers to exercise farming systems on a sustainable basis. In this respect, however, it is very easy for those who don't make the decisions to draw up a long list of what will be required to ensure sustainable agricultural development.

The TAC paper on sustainability discusses socioeconomic and legal determinants. It suggests that national and local governments give a higher priority to agriculture, pricing policies for both export and import commodities, the need to develop the necessary infrastructure to overcome constraints in the delivery of inputs to farms, transportation of commodities to market, the provision of marketing facilities, credit, extension, education, and research, including adequate staffing of such institutions.

Furthermore, tenurial rights should be determined in such a way as to sustain agriculture, especially in regions where women have no right to own land yet do most of the farm work. It is especially important to note that the TAC paper emphasizes the necessity of laws and regulations to control the use of land, to protect forests and rangelands from indiscriminate exploitation, and to control the use of water resources for irrigation and other purposes. This list could be extended to cover even more areas of concern.

However, it would be expensive to meet all these requirements, and unpopular laws and regulations would have to be introduced in poor African countries and in the small island countries of the Caribbean and Pacific. We know from political discussions in Europe and North America how difficult it is to provide funds for environmental activities, even in these rich countries.

This may lead to the conclusion that sustained agriculture in the developing countries may not be achievable and, as a result, decision makers may close their eyes to these problems. Such a pessimistic outlook may even be based on the normal time horizon for politicians of 10 to 12 years, with a maximum of 20 years. However, to speak of sustained agriculture requires many more long-term considerations. What can be done under these conditions? First of all, decision makers have to realize that sustainability is essential to the survival not only of people but of whole countries. Their inhabitants are threatened if preventive measures are not adopted. Furthermore, it has to be understood that these are problems to be solved on national, as well as on regional and international levels.

In order to achieve sustainability, priorities have to be set for national laws and regulations, as well as in agreements, or even treaties, drawn up for regional and international cooperation. There are a number of activities that can be launched without serious budget implications, but other activities require a reallocation of funds from less important projects to programmes of sustained agriculture. In donor-funded programmes, sustainability should be given the highest priority. Developing countries should be assisted, especially in areas, such as conservation of plant and animal genetic resources, that serve the international community as a whole.

In this respect, the Lomé Convention may be a model for less-developed countries and donors alike on how to accelerate both food production and sustainability.

Dissemination of Scientific and Technical Information for Sustainability

The literature on environmental problems is growing, and is consequently more difficult to digest. However, the bulk of this literature is on soil erosion, land degradation, indiscriminate forest clearing, and overuse of pesticides and fertilizer, all of which provide important evidence of the destruction of natural resources.

However, finding any practical scientific or technical information on achieving, implementing, or practising sustained agriculture under different climatic and soil conditions is very difficult, even in Europe and North America. In Africa and other parts of the developing world, scientific and technical information on sustainable agriculture appears to be virtually nonexistent.

The reasons are evident. First, until recently, research on sustainability, especially for tropical countries, was not a high priority. Only plant genetic resources or breeding for resistance received attention. Consequently, research results on sustained agriculture are meagre. Furthermore, scientists and experts working on problems of sustained agriculture in most cases do not have the time or interest to describe the methodology, analysis, and evaluation of trials and experiments. Others who may be interested do not have the means.

Normally, it is very difficult for young scientists to find magazines and journals that will publish their articles, and the fact that there are very few scientific journals in Africa and other parts of the developing world only serves to make it more difficult. As a result, scientific and technical information on sustainable agriculture is not widely disseminated and gets lost over the years because it is not properly documented or published. It is difficult to estimate how much research is repeated because it has never been written up and disseminated. Moreover, a great quantity of so-called grey literature is available in many agencies, but even this is not disseminated. For a number of reasons, this literature has not been published, but the information it contains could be invaluable to scientists, planners, and others interested in the field. Sometimes, it would be sufficient to merely duplicate and disseminate this information in its original form, and possibly translate it. In other cases, revision and compilation of a number of related texts would be useful.

One example of how grey literature can be made available for sustained agriculture is the *Atlas on the Agropastoral Potential of Sahel Countries* published by CTA (Technical Centre for Agricultural and Rural Cooperation) and IEMVT (the French Institute for Tropical Veterinary Medicine). This atlas includes statistical information, research results, and other information on livestock development, including botanical studies, transhumance, and mineral resources, a large part of which was collected over a period of more than 100 years by French institutions. This document gives planners, scientists, and other experts substantial scientific and technical information on sustainable agriculture in these countries. It is an especially valuable contribution to the field because these countries have been experiencing such severe problems with desertification.

Apart from the preparation of useful scientific and technical information, its availability is another serious problem in ACP countries. Governments and other institutions have only limited funds to purchase professional publications. Contrary to the situation in Europe and North America, developing countries are not confronted with the problem of how to manage the increasing professional literature, but of how to obtain it in the first place.

In this respect, the provision of coupons for the purchase of professional literature, the supply of books and subscriptions to professional magazines, and the delivery of hardware and microfiche to relevant institutions in developing countries will give decision makers, experts, and producers access to scientific and technical information on sustainable agriculture. Question-and-answer services, such as the one maintained by CTA for ACP countries, are also useful.

At present, together with the CGIAR Secretariat, CAB International, the U.S. National Agricultural Library, the Rockefeller Foundation, the Royal Tropical Institute, IBM (Europe), and a number of other donors, CTA is working on a new technology for scientific and technical information that will have great implications for sustainable agriculture in ACP countries. This CD-ROM technology (compact disc/read-only memory) would establish a large number of decentralized data banks in developing countries. This appears to be feasible for developing countries, since the cost and maintenance requirements for the system are reasonable, and it can be used by scientists who have not had special training in documentation and data processing. CTA is preparing a project to supply the system along with relevant training to ACP countries.

The Lomé Convention: Agricultural Cooperation and Sustainability

The EEC and ACP states signed the Lomé Convention to promote cooperation on economic, social, and cultural development in ACP countries, and to consolidate and diversify their relations in a spirit of solidarity and mutual interest.

The ACP countries are a varied group with different climates and constraints on agriculture and food production. The continent of Africa is deeply involved in searching for ways to combat drought and desertification in the Sahel and Southern regions, and to find alternatives to deforestation in the tropical areas. The island states of the Caribbean and the Pacific are concerned with the management of acid soils and also with the gradual disappearance of their tropical forests.

Concerned by the alarming reports of drought and desertification in the Sahel and other regions of Africa, while at the same time acknowledging that food and agricultural production were lagging behind population growth, the Lomé Convention advanced agricultural cooperation to the forefront of its several Titles of Cooperation. Among the various objectives of agricultural cooperation, it stated that agricultural research should be tailored to the national and human environment of the countries and the region. It called for improved farming methods while conserving soil fertility, and better integration of arable land and livestock farming.

The first part of the Convention, entitled "General Provisions of ACP-EEC Cooperation," recognizes that agricultural production, including forestry and fisheries, occupies a crucial position in the economies of the majority of ACP states.

Drought and desertification control became a special chapter in the Third Lomé Convention signed in December 1984. The text of the Convention reads:

> The ACP States and the Community recognize that the physical, economic and political existence of certain ACP States is threatened by endemic drought and growing desertification which destroy all efforts at development, in particular those aimed at achieving the priority objective of self-sufficiency and food security. (Art. 38.1)

The ACP-EEC Joint Assembly, also concerned about issues of development of sustainable agriculture, set up a working party to examine rural development and environmental problems in ACP states. From the recent trend of events concerning environmental degradation, it is almost certain that the next ACP-EEC Convention will stress agricultural and rural development based on sustainability.

Conclusion

The development of sustainability in agriculture is essential for two reasons:

1. to allow the necessary increase of food production to feed a rapidly growing population;

2. to protect and develop the productive potential of soils, water, and genetic resources.

Research for such harmonious development should be an on-going process and must be location-specific. NARS have to play a more central role in such a venture. Networking of research and the dissemination of its findings through scientific and technical information are becoming more and more important in the development of sustainable agricultural systems. The Lomé Convention, in its chapter on agricultural cooperation, shows concern for sustainability by encouraging protection of the natural environment. The Technical Centre for Agricultural and Rural Cooperation, established under the same chapter, is responsible for collecting and disseminating appropriate information to support this objective.

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Session III
Summary

Sustainability of Agricultural Production Environments

Introduction

Definitions

Both plenary speakers began their presentations with a brief review of the definitions and usages of *sustainability*. Carter observed that "sustainability as a concept has intellectual and emotional roots from different disciplines where it is used in a variety of contexts," and this has given rise to some confusion. Nevertheless the speakers found some definitions useful.

The Brundlandt Report on Environment and Development (Our Common Future) defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

As applied to agriculture, the CGIAR/TAC report described sustainable agriculture as one which "involves the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources."

These definitions capture the essence of the issue in a nutshell: the dual responsibility to satisfy human needs and to maintain the environment, now and for the future.

Carter noted the several dimensions of agricultural sustainability stressed by different authors, and supplied the list enumerated by Harwood:

- sustainability over time and generations;
- social sustainability of rural communities;
- economic sustainability;
- maintenance of genetic resources;
- minimization of environmental pollution;

• lowered use of industrial inputs (demand on fossil energy).

After describing very briefly the status of modern agriculture and the impressive gains that have been achieved with this type of agriculture, Carter raised several concerns which provide the impetus to change the current system, as well as the impediments to change. He discussed some of the methods that have received the most attention, such as integrated pest management, use of pest-resistant varieties, improved tillage practices, use of manure, legumes, and other chemical fertilizer substitutes. Carter concluded by pointing out that our inquiry into sustainability should go beyond the farm production unit to the whole of society, and that the analysis of alternatives should be viewed from a benefit/cost framework not only to producers, but also to consumers and the general public.

The Lomé Convention and agricultural sustainability

The contribution from one of the co-sponsors, the Technical Centre for Agricultural and Rural Cooperation in Agriculture, revolved around the concern of the Africa, Caribbean, and Pacific member-states of the EEC-ACP Lomé Convention for agricultural productivity and sustainability, the special problems they face, and the efforts necessary to assist them. Treitz and Narain stressed how the "Lomé Convention may be a model for both LDCs and donors on how problems of accelerating higher food production on the one hand and sustainability on the other hand can be dealt with," and recounted CTA's contribution to this objective by way of dissemination of scientific and technical information on sustainability.

Treitz and Narain also dealt with both development and research policy implications of sustainability as far as the ACP countries were concerned and their significance to the work of the IARCs and the donors who are dedicated to assisting these countries.

Group Discussions

Clarification of concept of sustainable agriculture

Two working groups sought to clarify Carter's use of low-input agriculture as a synonym for sustainable agriculture. Sustainability as a concept for one working group meant "increasing productivity while maintaining or improving the natural resource base," which "by necessity is a dynamic process." The other working group contended that "since demand inevitably expands through time, consideration of sustainability as a goal must be balanced with productivity objectives. Sustainability therefore should not and need not necessarily be equated with a low-input type of agriculture."

The origin of the terminology was traced by the first working group to the "substantial food surpluses which currently exist in developed countries and which have forced these countries to consider alternative patterns of land use or to reduce levels of investment in agriculture." The members of the group argued that "while this may be appropriate for high-input systems in developed countries, it may not be appropriate for low-input systems in developing countries."

For many developing countries whose agriculture is still struggling to modernize, the NARS leaders present wanted to make sure that the public concern for the environment does not overwhelm what they perceive as an equally compelling need to modernize their agriculture through additional external inputs. This concern was not lost on Carter, who, even as he used sustainability interchangeably with low-input systems, expressed that "in present farming areas using low-input practices that have evolved over generations, the pressure to boost food productivity via Green Revolution techniques and turn a profit means a shift toward the chemically intensive practices of the developed world."

The second working group proposed that in dealing with sustainability in agriculture, one should consider two broad agricultural production systems: high-input and low-input.

High-input systems. These systems are normally associated with inherently highly productive environments where the excessive application of pesticides and fertilizers and unsound agronomic practices can and have led to adverse environmental consequences. In these production systems, the emphasis will have to be on trying to maintain high production levels while moderating and/or controlling environmental degradation. The working group stressed that increased productivity from the naturally fertile production areas can be a means to relieve the pressure on less productive, marginal, and usually very fragile environments.

Low-input systems. These production systems depend largely on resources occurring in those environments or those which are available to the farming communities. They are less dependent on external inputs. The working group further noted that "there is increasing, though as yet limited, knowledge and practice which demonstrates that inherently less fertile and marginal environments can be managed more responsibly."

Predisposing conditions that lead to degradation of the environment

This section was contributed by one working group which correctly recognized a set of concerns expressed by all working groups as causes or predisposing conditions which lead to degradation of the environment. These same factors were cited elsewhere by the other working groups but in slightly different contexts. The fifth phenomenon was emphasized by both plenary speakers.

Five major causes or predisposing conditions can be identified as leading to widespread degradation of the environment:

- Increasing population pressure forces the cultivation of land not ecologically suited for food production.

- Poverty forces large segments of the population to eke out a living on marginal and fragile environments.

- Domestic energy shortages lead to excessive clearing of forests for fuelwood.

- Land tenure and social arrangements are not conducive to responsible stewardship of the environment.

- The rush towards modernization, made possible by advances in science and technology and the availability of cheap fossil fuel, has led to excessive use of fertilizers, pesticides, and other chemicals, and to the loss of genetic variability associated with monoculture and widespread adoption of genetically homozygous high-yielding varieties.

Degradation of the environment occurs even with low population growth and affluence but obviously environmental problems are aggravated by high population growth and poverty. And they are mutually reinforcing in their negative impact on the environment.

Land tenure and social arrangements stand for the web of social, economic, and political interactions which make sustainability so intractable. The complexity and human conflict pervasive in any consideration of sustainability derive from the differential costs and benefits of human activities. Thus, practices that appear justified individually in a private sense have a way of ultimately combining into a trend which is in conflict with the broader, longer-term interests of society. Much of the problem, and therefore, solution, lies in the extent to which these oftentimes conflicting interests can be reconciled.

Physical manifestations of environmental degradation

Three sets of concerns expressed by all working groups related to the physical manifestations of environmental degradation:

- soil and water losses;

- pollution;

• loss of genetic resources.

Land degradation, desertification, salinization, and other similar terms apply to conditions where there has been substantial and often almost irreversible loss of soil and water resources. Many consider soil erosion by far the more severe and urgent problem.

Pollution of the environment was described in terms of the residues from pesticides, fertilizers, and other chemicals used in agriculture which find their way into underground water, the food chain, and the agricultural produce which people consume directly. It was pointed out that misuse of inputs often results from ignorance, inadequate regulations for input use and enforcement, and inappropriate pricing policies. The exports to the developing countries of chemicals banned in the industrial countries were also deplored.

Moreover, there was some concern expressed over the safety of the farmers and workers who apply the pesticides. As Carter noted in the plenary, the danger these chemicals pose to farm workers is more acute and immediate. Surprisingly there was no discussion of farm manure and other wastes which is of great concern in developed countries and around major urban centers in many developing countries.

The development and widespread use of high-yielding varieties and livestock breeds, and the tendency towards monoculture associated with modern agriculture, lead to a potentially risky narrowing of their genetic bases. The violent swings of insect pests and diseases associated with the widespread adoption of HYV are manifestations of this increased vulnerability. The loss of genetic resources and variability is considered a serious threat to the long-term sustainability of agriculture itself.

Development Policy Actions

The development policy actions generated by the working groups may be organized in a number of alternative, equally plausible ways. One such array is

• population and poverty;

• land tenure and social arrangements;

• environmental conservation and management;

• public health and safety;

• genetic resource conservation;

- promotion of environmentally benign technologies;
- development and reorientation of research capacity in NARS towards sustainability;
- information, education, and political will and commitment.

Population and poverty as generic issues

The impact of population and poverty on sustainability in agriculture was recognized by all working groups, but these discussions were very brief. One working group suggested the management of demand as an obvious but necessarily easy remedial measure. Population control and changes in consumption habits and lifestyles would reduce demand.

Land tenure and social arrangements

One working group asserted that responsible stewardship of the land and the environment is often associated with ownership or traditional attachment to the land by community residents. Regardless of how true this may be in different societies and specific country situations, the principle is that governments must recognize the social, economic, and political complexities that govern the use of natural resources, and must therefore be prepared to adopt policies that promote the kind of behavior and production practices conducive to the conservation and proper use of the environment. Such policies will certainly include policies on private ownership of the land and tenurial management of lands in the public domain.

Environmental conservation and management

The proper use and conservation of natural resources would require various development strategies and actions. These were contributed during the discussions:

- establishment of monitoring and early-warning systems, both national and transnational;
- land classification and appropriate zoning regulations;
- rehabilitation and conservation of forests, watersheds, mangroves, grasslands, bodies of water, and other fragile environments;
- reforestation, including fuelwood production and agroforestry;
- land development such as terracing, irrigation, and drainage (especially to deal with salinity);

- outmigration and resettlement from fragile environments;

- provision of incentives to long-term private investments in proper resource use and development.

Public health and safety regulations

One working group suggested "stricter public health and safety regulation and monitoring" on the use and release into the environment of farm chemicals and pesticides. The monitoring should include the movement of these toxic chemicals not only in farm produce but also in groundwater and in animal life along the food chain, as well as their immediate impact on farm workers themselves.

Genetic resource conservation

Part of genetic resources are collected and maintained in genebanks, while others are kept in situ in natural reserves. Governments must be ready to commit their fair share of resources in the global effort to preserve and maintain our heritage of genetic resources.

Promotion of ecologically benign technologies

In the plenary, Carter discussed a number of practices under the rubric of low-input farming systems which are deemed innocuous or not as harmful to the environment as other current practices.

These technologies include integrated pest management, multiple cropping, manuring, use of pest-resistant varieties, zero tillage, etc. As the adoption of these technologies is influenced by their availability and price, governments must adopt policies that promote the adoption of ecologically benign technologies, and conversely, they must adopt policies that will penalize or discriminate against technologies that contribute to the degradation of the environment. For example, excessive levels of certain very dangerous pesticides are used because their availability is not regulated, and because they are imported very cheaply.

Moreover, one working group reiterated Carter's speculation that these new and different production practices will probably require different back-up institutions or service industries. Policies to promote the establishment of such support systems need to be established.

Development and reorientation of NARS research capacity towards sustainability

This policy action requirement was assumed in the working group discussions. Speaking of his experiences in the U.S., Carter noted that agricultural academic institutions are allocating only a small percentage of their budgets to sustainability or low-input research projects. The U.S. Department of Agriculture is funding a relatively small program of research and education on low-input sustainable agriculture. However in both cases the current support level is several-fold more than previous levels. His impression that the level of activity is similar in other countries was not challenged by any of the working groups.

Information, education, and political will and commitment

There was consensus on the general lack of awareness and understanding by the public of environmental issues in developing countries. According to one working group, "this lack of awareness is pervasive and should therefore be addressed as part of the curriculum from primary to tertiary evaluation. Moreover this must be supplemented by parallel efforts in non-formal education, i.e., through extension." This campaign for public awareness and understanding should include the political leaders as well to build a national consensus and commitment for sustainability and the enhancement of the environment. In fact, one working group observed that the lack of awareness of environmental problems applies even among scientists and researchers themselves.

The same working group strongly urged the formulation of a "Strategic Plan for the Environment" covering both national and regional levels.

Research Policy Actions

The priorities for research listed by the working group discussions fall into four broad research areas:

- social science;
- resource management;
- genetic resources;
- public health and safety.

Social science research

The social, economic, and political underpinnings of land ownership and use were recognized by all working groups as a very high-priority research concern in order to provide a more rational basis for policy. Research on the impact of land tenure on sustainable agricultural practices, the estimation of private and social costs and benefits, and the macro consequences of alternative low-input systems need to be undertaken to understand the problems better.

Resource management research

By far this broad area received the most attention from the working groups. The researchable topics mentioned by the working groups included:

- characterization and mapping of agroecological zones;
- soil erosion studies and utilization of marginal lands;
- salinity and water quality studies;
- irrigation, drainage, and efficient water use;
- integrated pest management; the farming systems research;
- watershed management;
- agroforestry;
- renewable energy sources and energy flows in agriculture.

These topics are usually included in the research portfolios of most developing countries. However compared with another broad research category, commodity research, allocations to resource management research are usually only a fraction of the former. This set of recommendations implies a substantial increase in research allocations for resource management research. Whether this is to the extent of "even at the cost of commodity research" as suggested by Narain was not resolved.

Genetic resource conservation research

The concern for genetic resource conservation research was expressed very strongly in only one working group. Perhaps one explanation is that genetic resource conservation and research are historically associated with the predominant commodity-type research now existing in most NARS and IARCs, and therefore do not need additional stress. The researchable topics mentioned included studies on land races, maintenance of gene banks, and application of biotechnology, particularly tissue culture for genetic conservation.

Public health and safety research

Included in this area were risk management, toxicology, and tolerance-level studies for pesticide residues, and environmental and water-quality monitoring research.

Open Questions and the Future Agenda

The time devoted to the discussions was sufficient to provide an opportunity for a lively exchange of views on this very complex issue, and to establish the need for NARS in developing countries to reorient current agricultural research from the type of research largely associated with commodities to that which increasingly looks at resource management and the social, economic, and political complications.

The working groups devoted quite a bit of time to the major themes for sustainability research; however, none of the working groups felt they had the time, expertise, or information to address the tough decisions of balance, priorities, division of labor, and comparative advantage and structure. One working group left the following very pertinent questions on future NARS and the international research policy agenda:

- What is the appropriate balance between research on sustainability and research on other concerns?

- What is the relative priority among the different sustainability issues?

- What should the division of labor be among the NARS, the IARCs, and the developed country research institutions and the universities?

- In terms of research structure and organization, how should the NARS organize their efforts to address sustainability questions more effectively?

Session IV
Mobilizing and Sustaining Support for Agricultural Research

A Global Evaluation of National Agricultural Research Investments: 1960-1985[1]

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The overall contribution of agricultural research to the process of long-run economic growth is well documented. But agricultural research is a risky business and research-output linkages are complex. Agricultural research is also time-intensive, and the site-specific characteristic of much agricultural technology contributes to relatively long lags in the diffusion of this technology, both within and between countries. Conventional wisdom is that 15 years or so are required to exhaust fully the output-enhancing effects of agricultural research, although recent evidence for the US suggests these effects may persist for as long as 30 years.

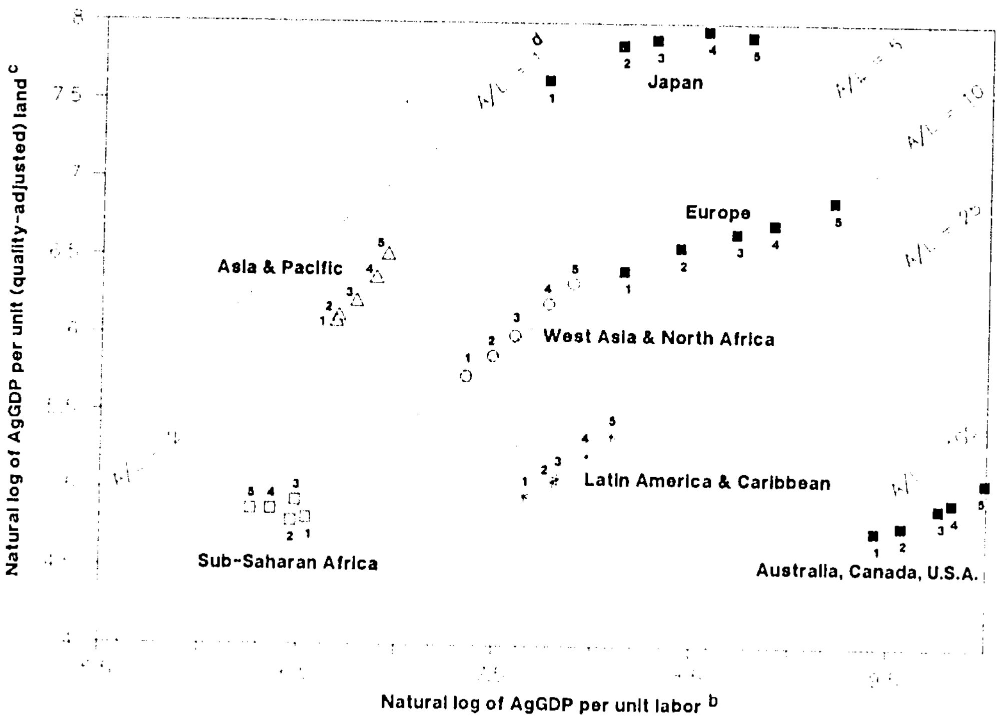
This all points to the need for an appreciation of the historical pattern of commitment to agricultural research in order to comprehend current developments in agriculture, as well as improve predictions concerning the course of future events in the sector.

Partial Productivity Indices

Before turning to some basic indicators of national agricultural research activity, it is instructive to review briefly the productivity shifts in global agriculture over the last 25 years. Average land and labor productivity gains in agriculture for four developing country regions and three developed country groupings over the 1960-1985 period are summarized in Figure 1.

For those conversant with the work of Yujiro Hayami and Vernon Ruttan (1985: 118-125), this diagram is no doubt familiar, yet differs from their earlier work in several important respects. Most significantly, the country coverage has been substantially expanded from 44 countries (27 developing) to 110 (90 developing). Agricultural output is measured here in value-added terms in contrast to the gross output –

Figure 1. Value-added productivity indices of (quality-adjusted) agricultural land and labor, regional averages, 1960-64 through 1980-85[a]



1 = 1960-64; 2 = 1965-69; 3= 1970-74; 4 = 1975-79; 5 = 1980-85

a) Sample consists of 18 Asia & Pacific countries; 20 Developed countries; 26 Latin America & Caribbean countries; 35 Sub-Saharan African countries; and 13 West Asia & North African countries

b) Labor is economically active agricultural population

c) Agricultural land is arable land and permanent crops plus permanent pasture (hectares of quality adjusted land)

d) A/L = Quality adjusted land per unit labor

Source: Authors' own calculations based on FAO and UN data

adjusted for intermediate inputs produced on-farm — measure constructed by Hayami and Ruttan. Also, the land variable has been adjusted here for country-specific variations in land quality. Land quality differences are taken to reflect variations in soil characteristics driven by long-run differences in average rainfall, plus differences in the percentage of agricultural land under irrigation.[2] In quality-adjusted terms there was consequently 40% more agricultural land in Asia and 24% less agricultural land in sub-Saharan Africa during 1980-85. Unfortunately, similar quality adjustors, which account for both over-time and cross-country differences in the human capital component of agricultural labor, are not presently available.

The regional productivity patterns in Figure 1 are quite revealing. Both land and labor productivity gained in West Asia and North Africa, Europe, and Australia, Canada, and the US as a group. Similar patterns of productivity gains occurred in Asia and the Pacific, and Latin America and the Caribbean, although both partial productivity ratios appear to stagnate during the 1960s in Asia, and the late 1960s to early 1970s in Latin America. Japan demonstrated steady growth in both partial productivity ratios until the mid-1970s. Thereafter, a slowdown in land productivity gains accompanied an increasing labor productivity ratio as the size of its agricultural labor force continued to decline steadily.

The pattern of productivity gains for sub-Saharan Africa is dramatically different from all other regions. The general picture is one of a stagnating ratio of output per unit of land and an erosion in the ratio of output per unit of labor. Relatively high population growth rates coupled with a low rate of labor absorption by the nonagricultural sector means that sub-Saharan Africa has not only lost significant ground in terms of labor productivity, but the production regime in its agricultural sector has, on average, increasingly substituted labor for land.

Figure 1 also maps long-run shifts in land-labor ratios at the regional level. West Asia, North Africa, and Latin America appear to have increased their labor productivity ratios largely through "yield increasing" technologies, with no discernible shifts in land-labor ratios over this 25-year period.[5] Japan has nearly tripled its average land-labor ratio over this same period, while Europe has doubled its ratio from 5 to 10 ha per unit labor. Australia, Canada, and the US have continued to substitute land for labor to the point that by 1980-85 they averaged 130 ha per unit labor. Meanwhile, for the Asian and Pacific region, gains in labor productivity have been smaller than gains in land productivity by an amount equal to the decline in the land-labor ratio.

Agricultural Research Expenditures and Personnel: A Regional Overview

The primary source for the agricultural research data presented here is a forthcoming ISNAR publication, which is a fully sourced and extensively documented set of research personnel and expenditure indicators for national agricultural research systems (NARS), where possible, for the 27-year period from 1960 to 1986 (Pardey and Roseboom, *in press*). The time-series data reported in this paper include estimates for 151 countries — but omit nearly all nonmarket economies, in particular China, Cuba, and Eastern Europe, for which plausible time-series data were unattainable. The country coverage is substantially larger than the 110 countries reported in the recent Judd et al. (1983, 1986) publications, and the 51 countries included in the earlier ISNAR/IFPRI report by Oram and Bindlish (1981). The data reported here therefore include observations on numerous small NARS which hitherto have been excluded from such global series, as well as completely revising and updating previously available country-level data.

Most significantly, all expenditure data were collected in current local currency units. This enabled us to minimize or at least standardize currency conversions. In particular, any currency manipulations of research expenditure data which were made represent a practical compromise to applying country-specific agricultural research deflators and agricultural research purchasing power parity indices. Inappropriate treatment of such matters can have non-trivial quantitative and qualitative impacts on the data (Pardey and Roseboom, 1988).

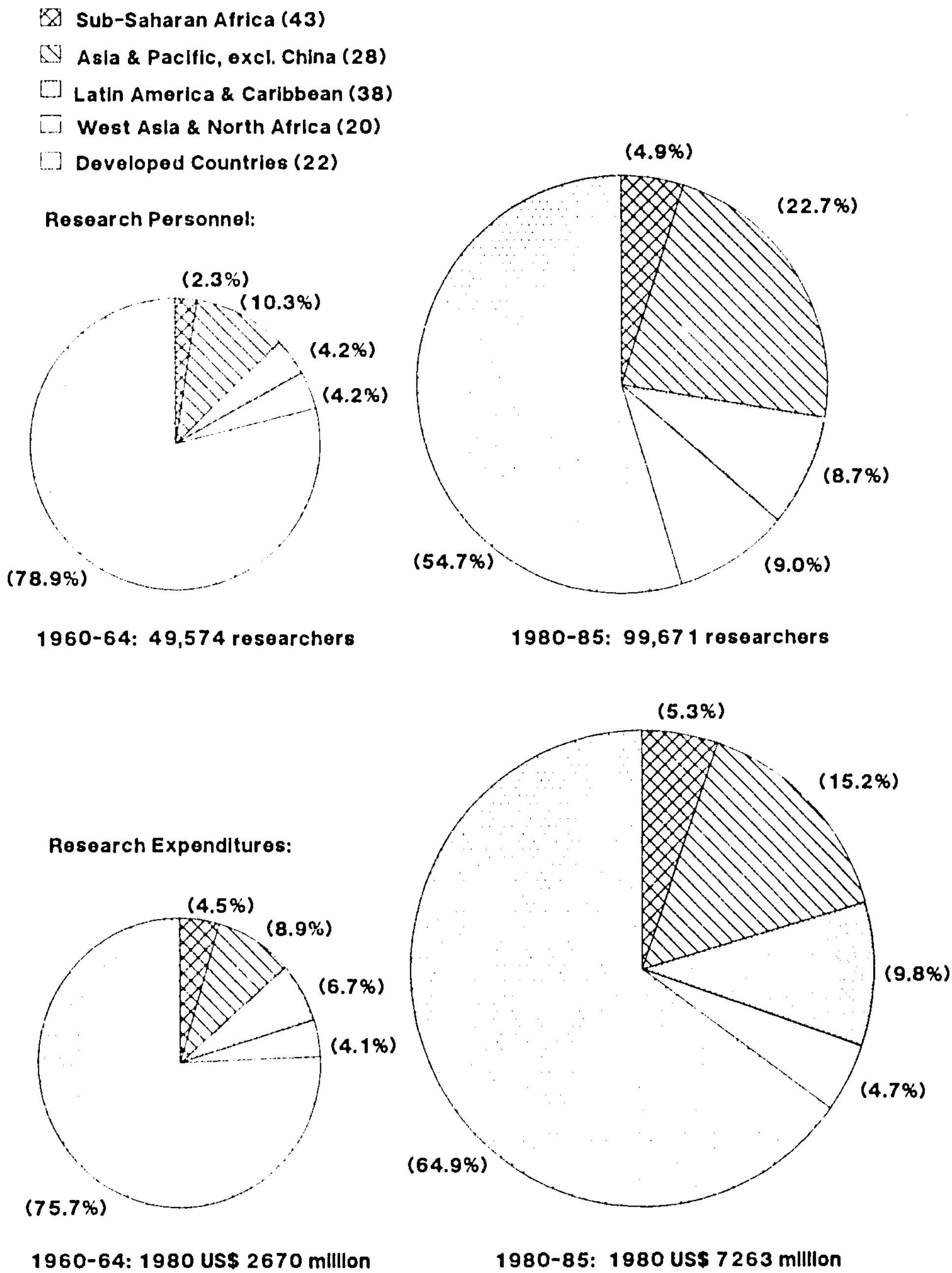
While we maintain that the over-time, cross-country commensurability of our research expenditure figures represents an improvement over previously available series, one should not underestimate the difficulties of ensuring consistency in such a series. To minimize the influence of spurious variability and missing observations, we chose to present all the indicators developed in this paper as quinquennial averages. While this may artificially dampen variability for data with strong trends, we would argue that five-year averages offer more realistic global comparisons than the point estimates used by many previous analysts.

Regional research expenditure and personnel shares

Figure 2 indicates that the total global number of public-sector agricultural researchers, measured in full-time equivalent units, has approximately doubled since 1960, from 49,574 to a current level of 99,671, while "real" expenditures have increased by a factor of 2.7, from US$ 2.67 billion to US$ 7.26 billion. These impressive gains in global agricultural research capacity nevertheless represent significantly lower rates of growth than the Judd et al. (1986) estimates of a 3.14-fold increase in research scientists – measured in scientist person-years – and a 3.68-fold increase in real spending over the 1959 to 1980 period. The substantially broader coverage of public-sector agricultural research institutions included in the present series, particularly for the earlier years, plus our attempts to maintain consistency in institutional coverage over time, probably go a long way to explaining these differences.

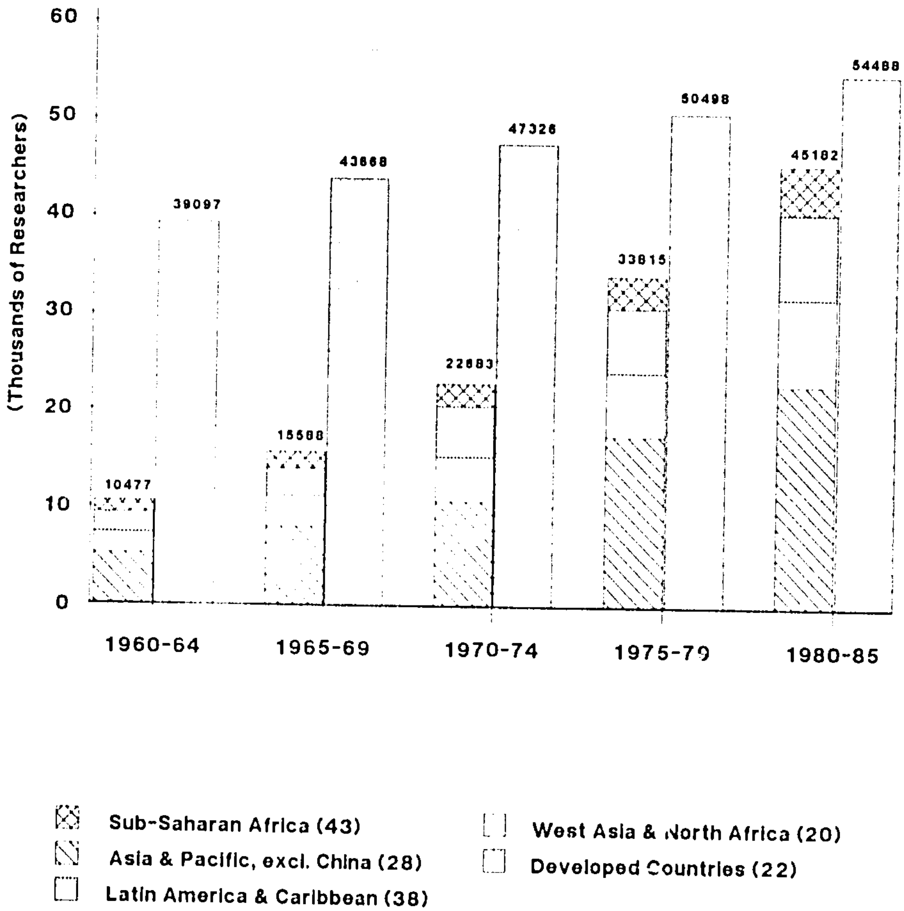
The 26-year period from 1960 to 1985 has experienced a marked shift in the developing countries' share of public-sector researchers. In 1960-64 developing countries, as a group, accounted for only 21% of the global agricultural researcher total, but by the 1980-85 period, this share had doubled to around 45% of the global total. The pattern of increase in research personnel for developing countries is similar across different regions, with all regions approximately doubling their share of the global total.

Figure 2. Regional shares of agricultural research personnel and 'real' expenditures (1980 PPP US dollars)



The overall result (Figure 3) is that the total number of research personnel in the developed countries has increased steadily, in a linear fashion, from 39,097 researchers in 1960-64 to 54,488 in 1980-85. By contrast, the total number of research personnel in the developing countries has grown exponentially from a mere 10,477 researchers in 1960-64 – approximately equal to two-thirds the size of the US public-sector research system at the time – to a 1980-85 average of 45,182 researchers.

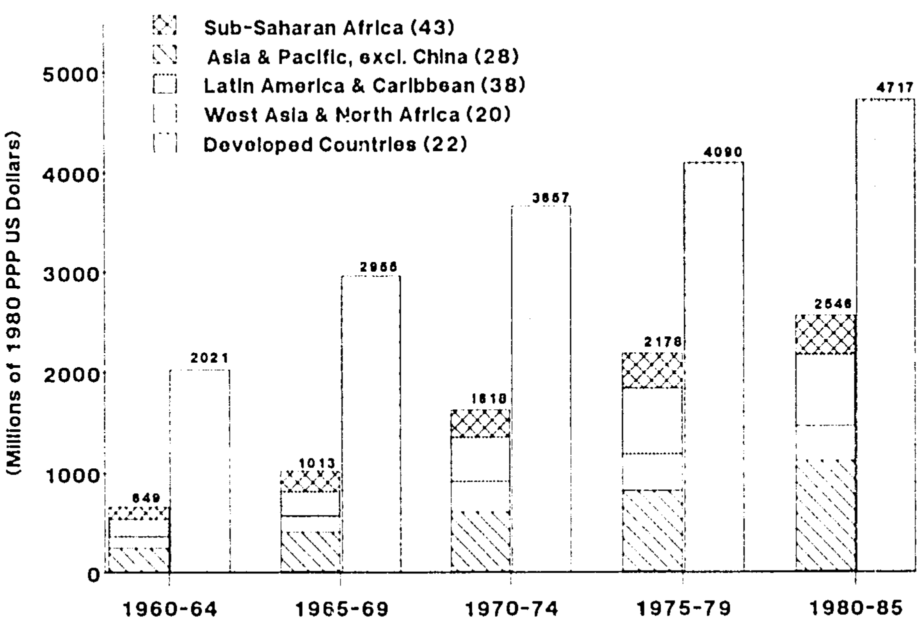
Figure 3. Regional development of the number of researchers (in full-time equivalent units)



China is a conspicuous omission from these figures, particularly when an attempt is made to assess agricultural research activity in Asia. It is difficult to obtain data on research personnel or expenditures for China which are commensurable with those reported for other countries. Nevertheless, we have pieced together a time series for the years following the cultural revolution which shows a rapid increase in research personnel from around 19,000 researchers in 1978 to a 1985 estimate of approximately 33,000.

The developing countries' share of the "real" expenditures of public-sector research agencies exhibits more modest gains compared with the research personnel figures (Figure 4a), increasing from around 25% of global expenditures to a 1980-85 average of only 35%. In contrast with the regional growth in research personnel, both developing as well as developed countries experienced a linear growth in real research expenditures. The asymmetry of these shifts in regional personnel and expenditure shares over time have direct implications for spending-per-scientist ratios, which will be discussed later in this paper.

Figure 4a. Regional development of 'real' research expenditures (1980) PPP US dollars)



"Real" research expenditures: A measurement problem

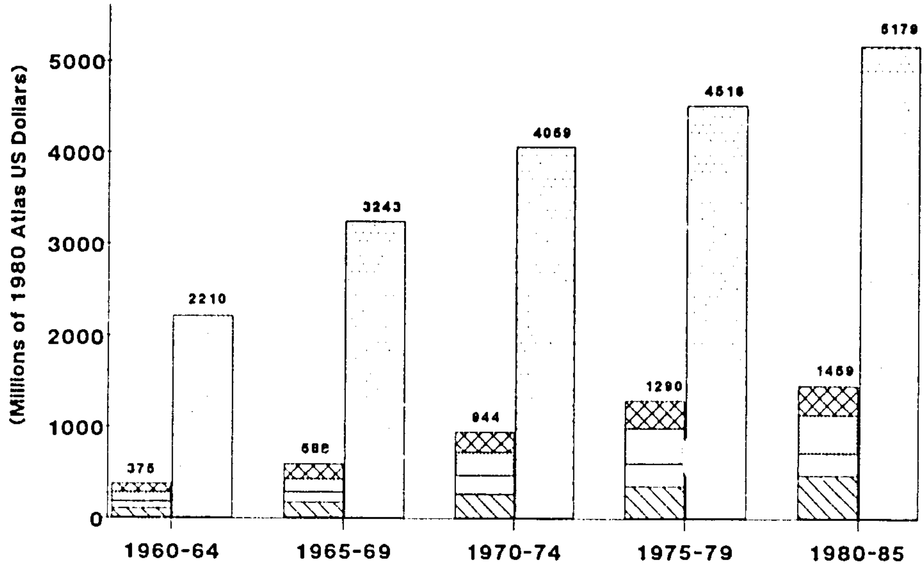
There are numerous problems associated with obtaining measures of real research expenditures that yield meaningful cross-country comparisons over time. Within a country, the rate of increase over time in the price of various inputs used by national research systems may not be well represented by a price index measuring more general rates of inflation in the national economy. The mix of inputs – such as labor, land, buildings, equipment, and miscellaneous operating expenses – varies during the life cycle of a national agricultural research system. A recent study in the US, for example, showed that while the state agricultural experiment stations currently spend only 8% of total expenditures on (physical) capital items, this figure peaked at nearly 29% of total expenditures in 1912, some 25 years after the formal establishment of the experiment station system (Pardey et al., *in press*).

There are also substantial differences in the average level of prices across countries. A great deal of effort by agencies such as the World Bank, the United Nations, and the Statistical Office of the European Community have recently been directed toward measuring the extent of these price differences in terms of purchasing power parity (PPP) indices. PPPs, by definition, measure the domestic cost of buying a bundle of goods and services in a particular country at its own prices relative to the corresponding cost in, say, dollars of the same bundle in the United States. When using PPPs to measure relative price levels, there is clear evidence that, as expected, average price levels are positively associated with per capita income. Moreover, there is overwhelming evidence that exchange-rate-converted research expenditure figures vary from PPP-converted figures in a significant and systematic manner.

Figure 4b uses World Bank atlas exchange rates to convert agricultural research expenditures into US dollars, and clearly implies a dramatically different regional pattern of real expenditures from the PPP-converted figures given in Figure 4a. In general, the atlas-converted figures appear to understate the level of real expenditures in developing countries relative to the PPP-converted figures, while overstating the level of real expenditures in developed countries. During the 1980-85 period, for instance, the PPP-converted figures suggest that real research expenditures in developing countries were 54% of the level of expenditures incurred by developed countries, while the atlas-converted figures put the ratio of developing to developed country real expenditures at only 28%.

Figure 5 decomposes the atlas- and PPP-converted expenditure figures to the regional level. PPPs suggest that average price levels in sub-Saharan Africa are not dramatically lower than those implied by Atlas exchange rates, so that measuring real research expenditures in terms of PPP rather than Atlas-converted dollars does not substantially increase the estimated volume of resources committed to research in the region. By

Figure 4b. Regional development of 'real' research expenditures (1980 Atlas US dollars)



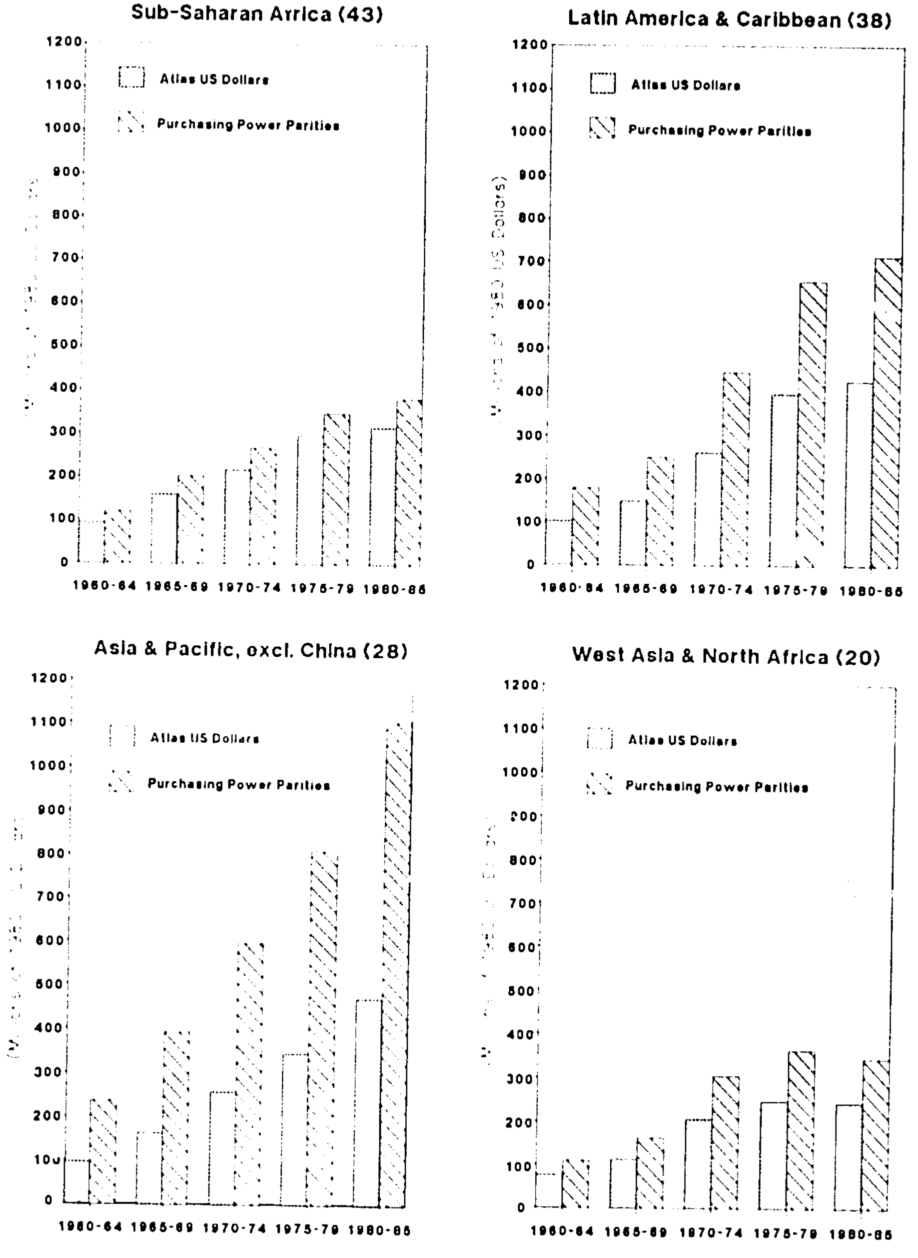
contrast, the Asia and Pacific PPP-converted expenditures suggest that real research expenditures in the region may be significantly higher than has hitherto been assumed if the relatively lower prices of domestic goods and services are factored into the conversion procedure.

The implications of these measurement issues are far-reaching, not only in the way we perceive the relative development of national agricultural research systems at a regional level, but also in terms of the implied rates of return to research and the like.

Real expenditures per researcher

Figure 6 consolidates the real expenditure and research personnel data by region over time into a series of ratios of real spending per scientist. With real expenditures measured in 1980 PPP terms, the relative ratio of spending per scientist for developed countries as a group exhibits a steady increase from around US$ 52,000 in 1960-64 to approximately US$ 86,500 in 1980-85. Meanwhile, the developing countries, on average, spent US$ 62,000 in 1960-64 – 19% more per researcher than developed

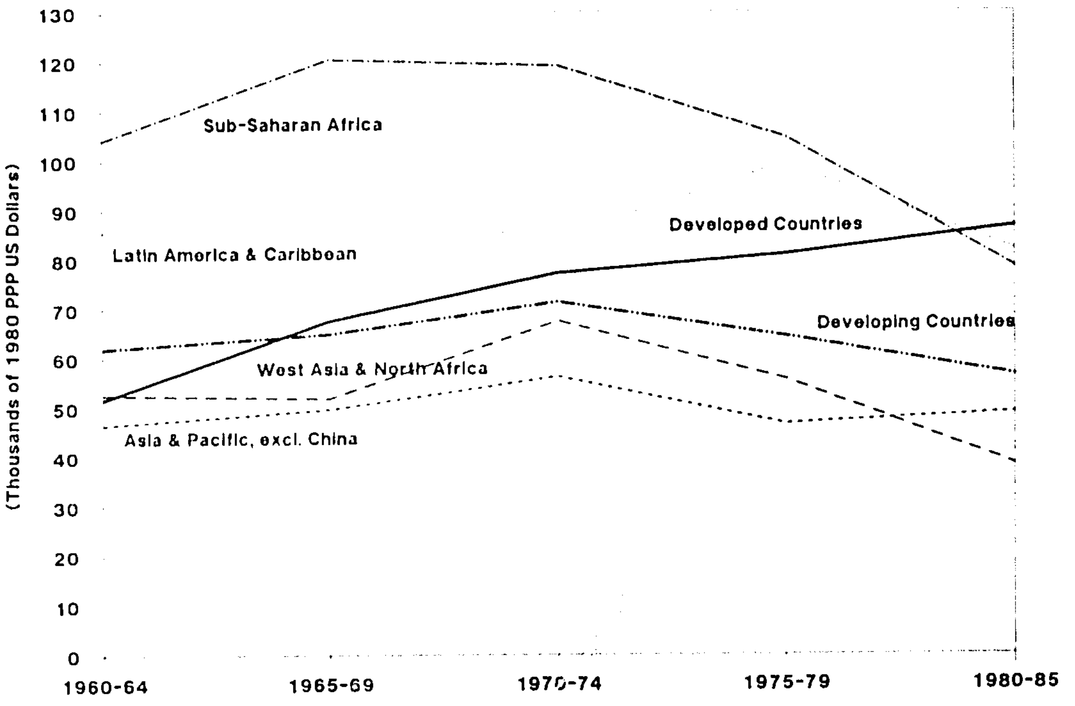
Figure 5. 'Real' research expenditures expressed in constant 1980 US dollars using either an Atlas exchange rate or a PPP index



countries for the same period – then peaked in their support per researcher during the early 1970s at around US$ 71,000, followed by a fairly steady decline to US$ 56,000 by the 1980-85 period.

Thus, the developed countries appear to have been moving steadily towards a more capital-intensive – both human and physical – research system over the past 25 years. Evidence based on detailed data from the US state agricultural experiment stations on the changing factor mix of their research systems points to a significant increase in human rather than physical capital over this period. By contrast, a sustained pattern of capital deepening does not appear to have materialized for many national agricultural research systems in developing countries. There has been an erratic, but nevertheless slight, drift upwards, on average, in spending per scientist in the Asia and Pacific

Figure 6. 'Real' research expenditures per researcher (thousands of PPP US dollars per full-time equivalent)



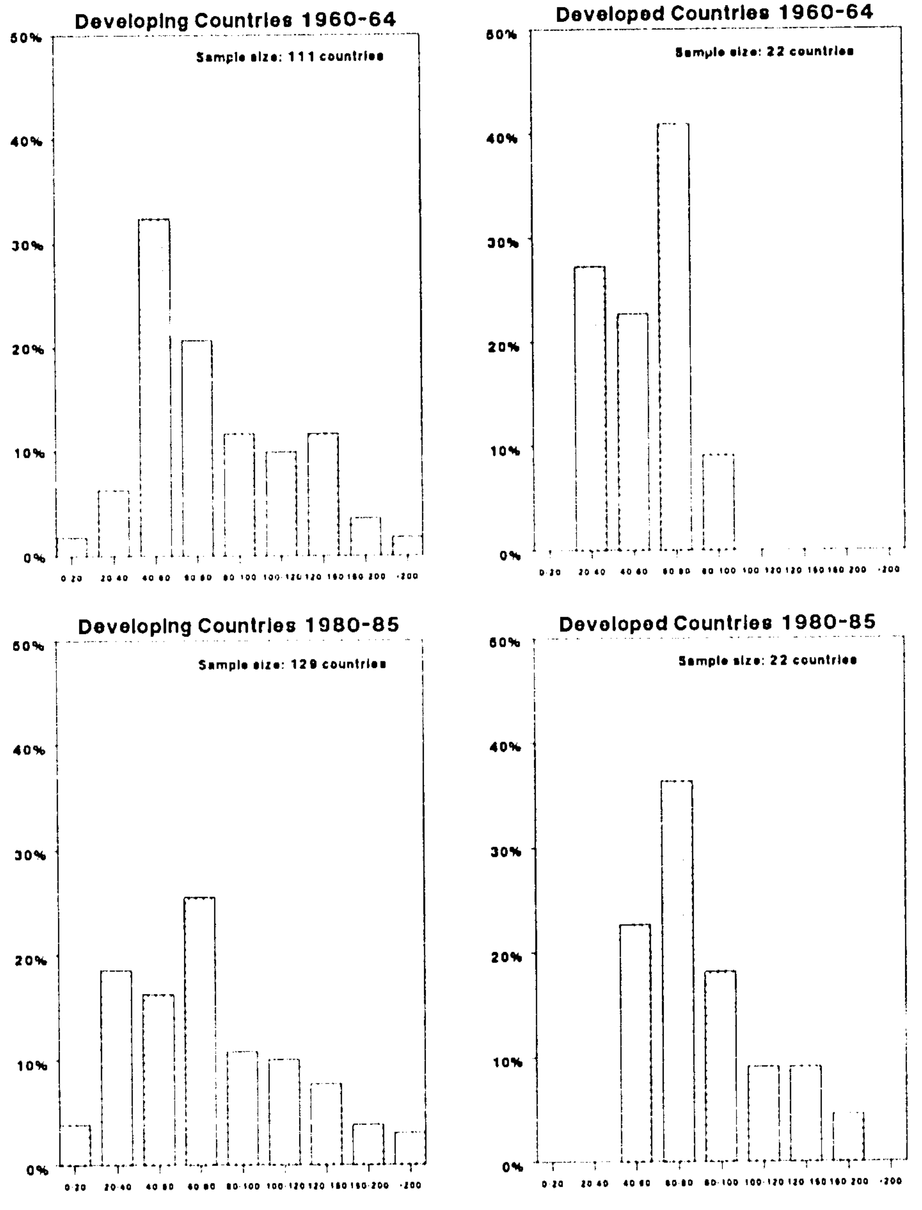
region. For the Latin America and Caribbean region, real spending per scientist remained fairly stable from the early 1960s through to the 1970-74 period, then rose during the later part of the 1970s to around US$ (PPP) 99,500 per scientist, only to fall back to earlier levels during the first half of the 1980s.

The pattern of real spending per scientist in sub-Saharan Africa over the last 25 years is again quite different from the other regions. Although average price levels in sub-Saharan Africa appear somewhat lower than developed countries, real spending per scientist on research performed during the 1960-64 period in sub-Saharan Africa was around US$ 104,000 in 1980 PPP terms, approximately double the corresponding developed country average. This ratio of real costs per scientist rose to around US$ 120,500 during the 1965-1974 period, followed by a rapid decline thereafter.

Figure 7 shows the frequency distribution of these expenditure ratios for 133 national agricultural research systems averaged over the 1960-64 period, and 151 systems averaged over the 1980-85 period. During the early period, 55% of all systems spent in the range of US$ 40,000-80,000; during the later period, 44% spent in this range. Interestingly, none of the developed countries in the sample spent more than US$ 100,000 per scientist during the 1960-64 period, while nearly a quarter of the sample spent in excess of this level in the later sampling period. There appears to be greater diversity in the pattern of real spending per scientist in the developing versus developed countries, which if anything, shows a tendency to increase rather than decrease over time. This development does not seem to be a function of the 18 new NARS that established research systems since the 1960-64 period, and are included in the later 1980-85 sample. Their ratios of spending per scientist were fairly evenly distributed across different cost ranges.

Explanations for the different patterns in spending per scientist, both over time and among regions, are varied, complex, and presently the focus of empirical study at ISNAR. They include a set of issues that are essentially internal to the research process, and a further set that are external to the process. This latter category relates to the political and economic forces that shape public support for agricultural research and are discussed in some detail in Pardey et al. (1988). Forces internal to the research proces influence, among other things, ratios of spending per scientist and include issues on economies of size, including the degree of fragmentation of national research systems; the stage in the life cycle of a research system; the relative price of research inputs, which directly influence the factor mix of the research process itself; and the very nature of the research problem under study.

Figure 7. Frequency distribution of average 'real' expenditures per scientist per country (thousands of 1980 PPP US dollars)



Conclusion

Disaggregating this regional data will help us understand the factors that influence the shifting patterns of support for national agricultural research systems that the data have revealed. Sharpening our estimates of the resource commitment to agricultural research – in both quantitative and qualitative terms – will also allow us to understand with greater precision the links between these growth-promoting investments, and the cross-country variation in agricultural productivity over time which we observed at the outset of this paper.

Notes

1. All figures presented in this paper are preliminary and may be subject to change as the primary data and/or conversion procedures are revised. Nonetheless, we expect that the general quantitative picture presented here will remain intact.

2. The methodology used to construct this international land quality index is a derivative of the procedure described in Peterson (1986).

3. Although Brazil increased the land under agriculture over this period by 85.6 million ha (58%), this was offset by the relatively rapid regional growth in the economically active population in agriculture.

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Determinants of Support for National Agricultural Research Systems

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Introduction

Leaders of national agricultural research systems (NARS) in developing countries are often told that they must increase their agricultural research effort if they are to have an impact on agricultural productivity in their countries. This is usually expressed as a need to raise the ratio of expenditure on agricultural research as a proportion of agricultural gross domestic product to levels approximating those of current high-income countries. System "doctors" keep confidently recommending their medicine in the form of a "2% solution".

This paper discusses and identifies new ways to improve the level of support for NARS. Most of ISNAR's work has been to help improve the organization and management of agricultural research. However, system leaders have often wanted ISNAR to help them improve the policy environment within which they must operate. One of the ways ISNAR can do this is to generate new information about the funding and operation of NARS which can improve the basis on which decisions are made. Another is to investigate structures which facilitate increased support and mechanisms for mobilizing resources. The policy dialogue must then involve national policymakers, NARS leaders and their clients, and stakeholders.

Over the last 2.5 years, ISNAR has been collecting and putting into commensurable form, time series data on human and financial resource commitments to agricultural research throughout the world (Pardey and Roseboom, *in press*). These data permit a preliminary analysis of support to research by countries at different income levels, and the development of expenditures through time.

In this paper, we consider the target ratio often used as a standard of adequate effort. Then, by looking at the components of this ratio, we attempt to identify the points of intervention and possible mechanisms which can help increase the level of support to NARS. From a discussion of points of intervention and mechanisms, we bridge the theory of public finance with issues of research organization and management. It is, therefore, at this early stage of analysis of the data, that a discussion of research directions is appropriate.

The Agricultural Research Intensity Ratio (ARI)

The Agricultural research intensity ratio measures public-sector expenditures on agricultural research as a proportion of the value of agricultural gross domestic product (AgGDP). The 1974 UN World Food Conference suggested that developing countries should aim for a 1985 target of 0.5% of AgGDP on agricultural research (UN, 1974:97). It was with the publication of the World Bank's Agricultural Research Sector Strategy that the "2% solution" was enshrined: a "desirable [agricultural research] investment target . . . would be an annual expenditure [recurrent, plus capital] equivalent to about 2% of agricultural gross domestic product" (World Bank, 1981:8).

In practice, comparisons of research intensity ratios have been useful to make policymakers aware of the importance others attach to agricultural research, particularly when their ARI ratio is significantly below those of similar countries. It also raises the question of why governments tend to underinvest in research when they expand their bureaucracies in all other respects.

However, such ratios may be misleading for a number of reasons:

- They are inherently unstable and can vary because either the numerator or denominator changes.

- Over time, the ratio should be expected to rise and fall as systems go through periods of investment and reinvestment.

- Countries with different resource bases and agricultural potential need not adopt the same strategy for agricultural development, nor be expected to give the same emphasis to research relative to other forms of intervention in the agricultural sector.

The result is that many research leaders are unnecessarily apologetic about their failure to reach the target, when in fact the target is a moving one and their effort is considerable for countries at their levels of income.

A decomposition of the agricultural research intensity ratio

It is worth decomposing the ARI into a number of components which have analytical significance. We create an identity in which the ARI is expressed:

$$ARI = ARE/AgGDP = (ARE/AE) \cdot (AE/BUD) \cdot (BUD/GDP) \cdot (GDP/AgGDP)$$

where

ARE = Agricultural Research Expenditure

AgGDP = Agricultural Gross Domestic Product

AE = Agricultural Expenditure

BUD = Total Government Budget

GDP = Gross Domestic Product

The expression on the right side is clearly identical to the original ARI ratio, but each component has some meaning in terms of agricultural development or public finance.

ARE/AE expresses the priority that is given to agricultural research as a share of total government intervention in the agricultural sector. We have called this the relative research expenditure ratio. It may be taken as a measure of the importance that the country attaches to research as part of its agricultural development strategy.

AE/BUD expresses the importance that intervention in the agricultural sector is given in the national budget. A careful monitoring of this ratio is important, especially if agriculture is represented as the "priority of priorities".

BUD/GDP may be either a measure of the fiscal capacity of the country or the fiscal effort of a country. In countries at an early stage of development, the fiscal capacity may be very weak and taxes concentrated on a few (often agricultural) commodities with a limited ability to generate revenue. However, as a country moves up the income scale, both its taxable bases and its administrative capacity to collect taxes improve. This makes the fiscal effort a matter of political will rather than good fortune.

GDP/AgGDP is the inverse of the share of agriculture in the gross domestic product, a good indicator of the structure of the economy and highly correlated with per capita income.

We use one additional ratio in our tables, the public agricultural expenditure ratio:

AE/AgGDP measures the public expenditure on agriculture in relation to the size of the agricultural sector itself. It encompasses several of the other expressions.

$$PAE = (AE/BUD) \cdot (BUD/GDP) \cdot (GDP/AgGDP)$$

Improvements in the ARI ratio, therefore, will be a result of efforts to increase the share of research in agricultural expenditures, the share of agricultural expenditures in the national budget, and the share of the budget in national income, while rising incomes will produce a declining share of the agricultural sector in the total national product.

The evolution of support: Evidence from the ISNAR Indicator Series

The data in this section are drawn from Pardey et al. (1988). Table 1 presents a vivid picture of what is happening to research expenditures through time and across countries at different income levels.

The data used in these comparisons have been carefully prepared to the following standards:

- The institutional coverage is comparable in all periods.
- Public support for agriculture, livestock, forestry, and fisheries is included.
- Calculations were originally made in constant currency units so that distortions were not introduced by currency conversions.
- The units were deflated to constant 1980 values using country-specific GDP deflators before performing any growth rate calculations.

There are a number of stylized "facts" which are evident in these figures:

- There has been a divergence in the ARI ratios with high-income countries raising their ratios faster than the low- and lower-middle-income countries.
- Public agricultural expenditure ratios (expenditure on agriculture relative to the size of agricultural product) rise significantly across income classes as countries move from net taxation of agriculture to net subsidization of agriculture. Note that the burden of this large expenditure on agriculture by high-income countries remains modest when spread over the non-agricultural population.

Table 1. Mean Agricultural Research Intensity, Public Agricultural Expenditure, Relative Research Expenditure Ratios, and Share of Agriculture in Total Public Expenditure by Time Period and Income Group (in Percent)

Income Group[4]	Agricultural research intensity ratio[1]		Public agricultural expenditure ratio[2]		Relative research expenditure ratio[3]		Share of agriculture in total public expenditure
	1970-85	1980-85	1970-85	1980-85	1970-85	1980-85	1970-85
Low	0.51 (21)[5]	0.55 (15)	5.08 (29)	5.73 (22)	10.10 (21)	10.34 (14)	9.53 (30)
Lower-middle	0.79 (32)	0.93 (26)	12.55 (37)	9.28 (29)	10.60 (31)	11.32 (24)	7.01 (41)
Upper-middle	1.00 (20)	1.09 (16)	14.83 (25)	18.00 (19)	10.36 (18)	10.96 (14)	5.00 (25)
High (General)	1.93 (19)	2.24 (18)	29.41 (19)	29.37 (17)	8.22 (18)	9.38 (16)	4.02 (20)
High[6] (Central)	1.91 (19)	2.24 (18)	23.21 (19)	23.98 (18)	11.18 (18)	14.72 (16)	4.00 (20)
Total	1.00 (92)	1.29 (75)	12.90 (110)	15.30 (87)	9.94 (88)	10.59 (68)	6.70 (116)

SOURCE: Authors' calculations based on date from Pardey and Roseboom (1987).

NOTE: Excluded from all calculations: Eastern European nonmarket economies, high-income oil-exporting countries (Kuwait, Libya, Oman, Saudi Arabia, Bahrain, Brunei, Qater), and People's Republic of China.

1. Agricultural research intensity (ARI) ratio = public agricultural research expenditure/agricultural gross domestic product.
2. Public agricultural expenditure (PAE) ratio = government expenditure on agricultural/agricultural gross domestic product.
3. Relative research (RRE) ratio = public agricultural research expenditure/government expenditure on agriculture.
4. Income Groups are defined using the World Development Report (World Bank, 1985) classification (per capita GNP in 1983 US$), where low = $400; lower-middle = $401-1635; upper-middle = $1636-6850; high = industrial market economies.
5. Figures in parentheses denote number of observations.
6. For comparative purposes, the ratios calculated using central government level expenditures only are included.

- The relative research expenditure ratio (ARE/AE), which measures the priority given to research within the agricultural budget, remains fairly constant across income classes.

- The share of agricultural expenditures in total government expenditures (AE/BUD) falls across income classes.

An attempt to draw conclusions from these stylized facts can be summarized: low-income countries appear to be making a consistent effort in terms of their budgetary allocations to agriculture and in terms of the share of the agriculture that is going to research. Their failure to raise their ARI ratios may be attributed to their limited fiscal capacity and the large size of their agricultural sectors relative to the total economy.

The importance of being able to spread the cost of agricultural research over a large nonagricultural population (often the primary beneficiaries), is demonstrated in Table 2. This table shows public spending as a proportion of economically active agricultural and nonagricultural populations (Pardey et al., 1988).

The total public agricultural expenditure per person in the agricultural population rises exponentially as incomes rise, while expenditures spread over the nonagricultural population remain modest. Agricultural research expenditure per person in agriculture rises modestly, while agricultural research expenditure per person in the nonagricultural sector scarcely rises.

The results of these analyses by Kang (*in press*) and Pardey and Roseboom (*in press*) suggest that the fundamental limitation to increased public support to agricultural research in developing countries may well lie in the financial and political constraints imposed by overall spending capacity, and agriculturally specific levels of public-sector spending. It suggests that we should be moderate in our expectations about the potential for large increases in public-sector funding of agricultural research in low-income countries.

Points of Intervention: Structural and Fiscal Improvements

Having recognized the difficulty of achieving increases in the ARI because of the structural and fiscal difficulties facing low-income countries, we still believe there is room for improvement if the right policy environment can be created, if the right mechanisms can be put in place to tap potential funding for research, and if resources are used in ways that encourage additional efforts by national governments. However, the need for continuous donor support is evident, particularly at the level of the low-

Table 2. Public Spending as a Proportion of Exonomically Active Agricultural and Nonagricultural Population (1970-85 Average)

	Economically active agricultural population	Total government expenditure per capita	Total agricultural expenditure per		Total agricultural research expenditure per	
			Agricultural population	Nonagricultural population	Agricultural population	Nonagricultural population
	(%)	1980 U.S. dollars				
Low	76.9 (37)[1]	245 (29)	30 (28)	125 (28)	2.6 (28)	10.9 (28)
Lower-middle	51.5 (49)	1093 (44)	164 (41)	157 (41)	16.7 (42)	14.6 (42)
Upper-middle	29.0 (71)	2966 (61)	656 (57)	232 (57)	58.5 (59)	14.4 (59)
High	9.5 (20)	7100 (20)	3294 (19)	296 (19)	239 (20)	19 (20)
Total	47.1 (137)	2311 (120)	768 (111)	188 (111)	61 (112)	15 (112)

SOURCE: Authors' calculations based on data from Kang (*in press*) and Pardey and Roseboom (*in press*).
NOTE: All expenditure figures first deflated to 1980 constant local currency units using country-specific implicit GDP deflators, then converted to US dollars using 1980 purchasing power parity indices from Summers and Heston (1988).
1. Figures in parentheses denote number of observations.

and lower-middle-income groups which are experiencing structural changes in their economies. The need is to "help them over the hump" to the point where rising fiscal capacity and growing nonagricultural sectors make sustained support to research easier.

Moving from the stylized facts, we turn to the need for research into the structures and the mechanisms which will improve the policy environment, and increase the flow of resources to agricultural research. Recognizing that it is virtually impossible to make a neat separation, there are structures and mechanisms that appear to be aimed at three types of improvement:

- improving the fiscal effort of the government, which enables it to carry out more of all development activities;
- improving the policy environment for agriculture: raising the ratio of public agricultural expenditures in the national budget;
- improving the policy environment for agricultural research: raising the share of agricultural research within the agricultural budget.

Increasing the fiscal effort

It is arguably beyond the competence and the mandate of agricultural research leaders to concern themselves with general questions of public finance. However, public finance issues are intimately bound up with the success of technology generation and transfer efforts. Distortionary taxes or exchange rates, deficit-induced inflation, and debt-imposed austerity directly affect the path of agricultural development.

Although low-income countries are hard pressed to meet claims on their resources, and there are recent indications that the real value of government's share in the national income is declining in recent years after a period of secular increase, there remains some scope for increasing the share through improved fiscal practices. It is important to note that even small increases in the percentage share of the national income that come to government can mean large increases in the development effort if they are reserved for this purpose. Assume, for example, that a low-income developing country succeeds in raising its fiscal share from 13% to 15% of the national product. If it was previously investing 30% of its budget in development activities, an additional two percentage points of national income would raise the investment rate from approximately 4% to 6% of national income – a 50% increase in development effort. It is for this reason that we should not ignore improvements in fiscal capacity as crucial to improving support for research.

Table 3 shows the pattern of central government revenue as a percentage of gross domestic product by level of income and over time. The low- and middle-income countries have been making efforts to increase the share of the government in national income over time. Moreover, as a country rises from a lower to a higher income class, its fiscal effort rises. The critical increases take place in countries in the lower-middle-income group. It is here that special efforts must be made to ensure attention to agriculture in the expenditure priorities of governments. The conclusion must be that there is still room for "political will" to play a role in raising development efforts.

Table 3. Total Current Revenue of Central Government as Percentage of GDP

Income group	1972	1986
Low income	–	15.4
Lower-middle income	16.7	21.4
Middle income	19.1	24.0
Upper-middle income	20.3	25.0
Industrial market economies	21.6	24.1

SOURCE: World Bank (1988).

Improving the policy environment for agriculture

The principal lesson for agricultural research managers seems to be that the agricultural research system must devote some of its scarce resources to analyzing the policy environment. Where decisions are made by economists and planners in ministries of finance and planning, agricultural research institutes must contribute to decision making through improved information, analysis of alternative strategies, and building political support for its activities. There are several activities which are directly in the research mandate of the institutes:

- Analysis of macroeconomic policies which distort the type of technology demanded by producers and impinge on the success of adoption of appropriate technologies. CIMMYT's work on domestic resource costs of wheat versus livestock and potatoes in Ecuador is a good example of the policy dilemma facing research leaders and the role of economic analysis in making decisions.

- Analysis of the rate of return to investment in research to document both the high returns gained historically, and provide some guide to potentially high returns in the future. It is as important to be able to identify what activities should not be undertaken as to make a case for more resources in general.

- Documentation of invisible returns to research. These are the cases where research has prevented major losses to disease, drought, and insect pests, gains which are not always recognized as the equivalent of production increases.

In short, if agricultural research does not invest in the policy dialogue, it cannot complain that its message is not being received.

At the present time, we are not able to make any categorical statements about the impact of organizational structure on the allocation of public resources to agriculture. Some preliminary hypotheses to be tested, however, are:

- Where agricultural development is fragmented across many ministries or parastatal organizations, and where livestock, forestry, and fisheries are competing with cropping to the neglect of conservation and natural resource management, the sector as a whole may suffer from a weak and fragmented message with a negative effect on the resources it receives.

- Large systems which can support decentralized taxing and expenditure power to a degree may encourage increased levels of total support to the agricultural sector. Decentralization associates taxation more closely with the benefits of research, and makes taxpayers more willing to bear the costs.

These are hypotheses which over time we hope to be able to study in greater depth. There is still a need to examine the determinants of agriculture's share in the national budget and the political and organizational factors which affect this ratio. Of particular interest should be the lower-middle-income economies where the fiscal base of the economy is changing rapidly, and the share of agriculture in the economy is declining.

It is with these countries that a commitment to agricultural research and development must be built into the tax and budgetary system so that the public agricultural expenditure ratio can be raised.

Improving the level of resources to research within the agricultural budget

In this section we look first at structural improvements which increase the support of client groups to agricultural research. This is followed by a consideration of fiscal mechanisms to tap new funding sources in the agricultural sector.

Attempts to increase the share of public agricultural expenditures going to research may not be separable from measures designed to increase the overall level of resources going to agriculture. Public finance specialists have noted that raising the share of a particular item may require new sources of revenue. Averch (1985:179) said:

> The budget procedures currently used by S&T (science and technology) bureaucracies rest far more on historical shares and constituent pressure than they do on the most primitive notions of the marginal productivity of research dollars in alternative uses. In part, this is why the bureaucracies are always demanding new resources; their ability to do anything new depends on receiving new inputs, since they are unable to reallocate the resources they have.

The role of constituent pressure. The need for research to establish the support of its constituents was expressed strongly by Dr. W.K. Gamble (1984:51) before a group of Latin American research leaders:

> Experience suggests, however, that the long-term viability of agricultural research systems depends on the emergence of organized producer interest groups who are willing and able to exert influence on the legislative and executive processes. This is because the support of agricultural research forthcoming from finance and planning ministries, given the pressures under which these ministries must operate, is not dependable.
>
> To assure reasonable domestic levels of fiscal support on a regular basis, national research program leaders and program beneficiaries have to commit themselves to a sustained political development effort.

This statement fits the Latin American environment and reflects a political economy approach expressed by many Latin American writers. Dr. Eliseu Alves has argued convincingly that periods of crisis provide opportunities for research institutions to gain the commitment of policymakers if they find and use the best strategy for their own situation (Alves, 1987).

The question of whether or not coalitions of agricultural groups always succeed in raising support to agricultural research is seen in a different light by Browne (1987:83, 87), writing about the land-grant system. Although most has been written about the responsiveness of the land-grant institutions to their constituents, where more than 80% of the land-grant system's resources come from sources within the state, Browne notes:

> The most extensive and detailed statements of support (for research) come from those interests that are some part of the research effort . . . . Policy positions critical of agricultural research are surprisingly extensive and broad based.

The criticisms of agricultural research, coming from agricultural groups themselves, are diverse and often contradictory. Research is seen as benefiting universities rather than farmers, producing products suitable for industrial processing rather than food which is tasty and nutritious, and introducing technologies which neglect the environment. The conclusion of Browne's thesis is that the veto power of offsetting coalitions will prevent any change in the research agenda since nothing will be seen by all groups as an unambiguous improvement. Meanwhile, the negative chorus of voices may adversely affect overall appropriations.

Institutionalizing support. The move which took place in Latin America to create autonomous institutes in the 1960s and 1970s was intended to make research more responsive to its clients and stakeholders. The move was generally aided by long-term institutional support from USAID, which saw them as a new flexible way of getting research out from under the bureaucracy of the ministries. However, there was a tendency for the institutes to behave as if their constituency lay in the donor community and not in the domestic political structures. USAID began to suffer donor fatigue after many years of declining national support, caused in part by the political isolation of the autonomous institutes.

The latest trend in Latin America is the creation of private research *fundaciones*. They are characterized by the predominance of private-sector agricultural interests on their boards, an attempt to establish endowments to ensure a stable resource base for research, and a mandate to support new agricultural efforts. Through their boards they are expected to become closer to producers, and be responsive to the need for research on nontraditional crops that national research institutes historically are poorly equipped to handle.

The establishment of foundations was one way of overcoming donor fatigue, and fit well with the philosophy of the donor government, which was stressing private-sector initiatives in all areas. Unfortunately, their rhetoric of being a "private-sector alternative to failing national systems" went beyond the reality. They use public-sector funds (coming from aid donors), few of them have their own research capacity, and they must rely on human resources that they draw away from the national institutes.

Whether they represent an increase in total funding to the system (by preventing a decline in aid), or a diversion of resources which would otherwise be available, is yet to be seen. They will face a test of sustainability when the aid-funded projects which initiated their activities arrive at term (Sarles, 1988).

Tapping sources of funding within agriculture. The agricultural sector, however, may often have untapped sources of research and development funding that can be reinvested in the sector. These include support by producer groups for research, production cesses levied by industry councils or authorities, earmarking taxes to research, and formula funds that tie increased government contributions to commitments by donors and other sources of funds.

Production cesses, often voluntarily levied by the producer organization in support of research and development activities benefiting its members, have been valuable sources of research funding for many commodities. They have been credited with at least two advantages:

- They provide an autonomous core of resources which can be used to ensure continuity of the research cadre.

- They are linked closely to producers and ensure that the system is responsive to their needs.

They have proven to be most feasible when the commodity (usually an export crop) faces an elastic demand, when producers can organize themselves to capture the benefits from research (either by appropriating the land suitable to the crop or through marketing the output), or when the industry is facing a crisis and mechanisms are created for an orderly diversification out of the crop.

Research funded by cesses, however, has certain disadvantages. The cess may have a disincentive effect, the base to which the cess applies may be shrinking secularly, and market instability may make forward budgeting uncertain. However, as the case of coconuts in Sri Lanka demonstrates, an institute funded by cesses can still enjoy the advantages of an autonomous core without ceding their right to get additional support from the general budget (Senanayake and Herath, 1981).

The earmarking by the government of certain sources of tax revenue for specific research purposes has not been tried frequently, although earmarking taxes for development is common. Earmarking tends to work well under certain conditions:

- where the objective of the expenditure is universally accepted as "good" (such as health or education);

- where the benefits of the research are recognized and can be appropriated by those who must bear the tax.

Earmarking may also be attractive because many of these characteristics may be present:

- It may substitute for decentralization of tax and expenditure authority where governments are highly centralized. (Taxes on a highly region-specific commodity which are spent on that commodity may prevent the feeling that the region's wealth is being siphoned off to the central government.)

- Once established, an earmarked tax obviates the need to engage in annual political infighting for a budget, although establishing it may require a major political effort.

- It may provide a stable funding source where the tax is linked to the export (foreign exchange) value of the crop and the domestic currency is unstable.

- It may control a tendency for central government to absorb all revenues where a region or sector lacks confidence in the central government's use of discretionary income.

- It may increase donor commitment to a particular activity through some form of linked support.

However, earmarking has certain disadvantages which may arise at some stage in the process:

- It introduces rigidities into the fiscal system. Expenditures may be too rigidly tied.

- Administrations controlling such receipts may build power bases from which they can refuse to relinquish their funding even after the objective for which the tax was earmarked has been achieved.

- They may become a permanent taxing authority outside of the regular public finance system which prevents a reallocation of resources to higher priority uses.

- They may not provide elastic sources of revenue for the sector they are funding either because the sector is facing a declining market or the tax itself has significant disincentive effects.

Earmarked taxes do not necessarily have to come from the commodities they fund or even the agricultural sector. Other candidates include imported articles for mass consumption, luxury goods, and excise taxes on alcohol or tobacco (demerit goods). The condition for success seems to be that the objective is accepted by those who must bear the tax and they have few ways of avoiding it.

New sources of domestic support – Private-sector investment

Up to this point we have stressed methods of increasing public support to agricultural research. There is now the reemergence of what is being called the "private interest" view of the public sector. It recognizes the imperfections in the public sector's allocation of resources, and argues that the government should invest its resources in a way which encourages a maximum contribution from the private sector. The essential complementarity of public-sector and private-sector research must be exploited in a way which draws additional resources from the private sector (World Bank, 1988).

As Echeverria (1988) concludes from his study of maize:

> Complementarity between public and private research contributes to the rate of technical change in agriculture. Farmers will benefit by a larger role of the private sector in developing, transferring and marketing better maize seeds. Public research and regulatory policies should be directed to stimulate private involvement in R & D and seed production by strengthening the public research programs, by training scientists, and by keeping research, production, and marketing regulations to a minimum in order to assure quality and competition.

In order to develop and capitalize on this complementarity, a number of preconditions need to be met (IICA-EDI, 1988):

- New legal arrangements need to be developed which provide for public- and private-sector cooperation, if only to overcome decades of competition and mutual suspicion.

- Incentives need to be provided for industrial support to agricultural research, carried out by, or in association with, the public sector.

- Structure changes need to be made which facilitate private-sector participation in decision making.

Once these preconditions are met, a number of mechanisms which help implement an enlarged commitment of the private sector can be developed. These include public/private-sector consortia for research, contract research by national research institutes and provincial development corporations, and private foundations.

Conclusion

Bringing the various elements of this paper together, we may argue:

- Developing countries have been making progress in raising their fiscal efforts, in allocating public funds to agriculture, and in assigning importance to agricultural research.

- A particular effort is needed to help lower-middle- and middle-income countries to maintain their concern with agriculture during periods of structural change in which the taxable bases are increasing and the share of agriculture in gross domestic product is falling. It is in this group of countries that the opportunity to raise the ARI is greatest, if only by taking advantage of the structural changes, and without insisting on an increase in the share of the agricultural budget going to research.

- Research leaders have a responsibility to understand the fiscal trends at work, to build political constituencies that support their claims to resources, to contribute resources and political efforts, to participate in the policy dialogue, to propose new sources of resources to meet their needs, and to use the resources so obtained for widespread social objectives and not priorities set by special interest groups.

- Including these functions in the tasks of the research system has important implications for the way research is organized in a country. New structural forms to exploit the complementarity of public- and private-sector research are required.

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Sustainable Institutions for African Agricultural Development

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The true measure of the success of a program of international and technical collaboration is not in its accomplishments during the period it is in force but rather in what happens after foreign aid has been withdrawn.

George Harrar, 1967

Introduction

The theme of the Bruntland Commission is sustainable development, a message that has been greeted with applause in rich and poor countries. The sustainable message has spread like wildfire, and 40,000 copies of the English edition, *Our Common Future*,[1] were sold in the first year. But the report sheds little light on African agriculture and on the development of sustainable institutions. Neither does the report by TAC (1988), *Sustainable Agricultural Production*, shed much light on the critical question of developing sustainable institutions.

This paper presents some thoughts on the development of sustainable institutions for African agricultural development. The focus is on strengthening the three core institutions – research, training, and extension – that form the institutional base of African agriculture. Primary attention is devoted to strengthening national agricultural research systems (NARS), and secondary attention, to training and extension.

A sustainable NARS is defined as one in which domestic political support is mobilized to provide adequate domestic financing of all core salaries and operating expenses of the national agricultural research system. The performance and sustainability of agricultural institutions is examined over two 30-year periods: the colonial period from 1930 to 1959 and post-independence from 1960 to 1988. This historical assessment raises some longer-term issues to ponder on strengthening African institutions over the coming 30 years, 1990 to 2020. Finally, some of the implications are explored for African states, donors, the CGIAR, and ISNAR.

The thesis of this paper is that after a third of a century of independence, many African states are several generations behind Asia and Latin America in terms of their stage of scientific, political, and institutional maturity. A few countries in Africa are probably one or two centuries behind Latin America and Asia. This is a sensitive topic that was shunned in the 1960s and 1970s and is only slowly starting to be discussed openly. For example, the respected Africanist, Colin Legum, recently observed that as colonial powers withdrew from the continent in 1960, they "left behind them a series of national states, but very few nation-states. The level of development of the continent's nation-state was still roughly equivalent to that of Europe or China in the fourteenth and fifteenth centuries – and certainly no later than the seventeenth century" (Legum, 1985: 24).

It is hypothesized that the stage of institutional maturity of individual African states will play a critical role in determining the type, amount, and sequence of foreign aid that can be absorbed with integrity. But most donors normally ignore the stage of institutional maturity of individual African states and prepare a continent-wide strategy to strengthen institutions such as a national agricultural research system or a national extension service.

The stage of institutional maturity of African countries relative to Asia and Latin America is beginning to receive attention from researchers. While much of the comparative scholarship on Africa and Asia centers on drawing insights from Asia's development experience for Africa, there are a few studies which deepen our knowledge base and eschew policy prescriptions. Two demographers studied the relationship between the stage of development and the speed at which family planning was adopted in Asia and Africa and concluded that the slowness to adopt family planning in Africa is "not explained by the African countries being at an earlier stage of socioeconomic development" (Caldwell and Caldwell, 1988: 19). The Caldwells contend that African family structures and economic and religious attitudes towards fertility severely limit the ability of African states to implement forceful family planning programs. But there are many puzzles about the dramatic differences between Asia, Latin America, and Africa in terms of life expectancy. For example, even though Sri Lanka and Sierra Leone both had per capita incomes of $330 in 1983, the life expectancy was 69 years in Sri Lanka, compared to 38 years in Sierra Leone (Behrman and Deolalikar, 1988). A recent study of 25 World Bank-financed agricultural development projects in East Asia, Latin America, and Africa points to substantial differences in the sustainability of agricultural projects by continent. Instead of evaluating projects immediately after project completion (normally five to seven years after projects had started), the projects implemented between 1969 and 1980 were studied between 1980 and 1984. The surprising finding was that all of the 10 projects in Latin American and Asia were considered economically sustainable, while only two of the 15 projects in Africa were economically sustainable (Cernea, 1987: 4).

The findings point to differential sustainability rates between Africa and Latin America and Asia and suggest that projects for Africa may have to be designed differently than those in Asia and Latin America.

The African Development Context

In 1957 Ghana, formerly the Gold Coast, attained its independence amid an outpouring of joy and high expectations. Three years later in 1960, 17 additional countries won their independence, thus explaining why 1960 is often referred to as the date of Africa's independence. Today 45 countries, totaling around 500 million people, make up sub-Saharan Africa (Figure 1). But despite the euphoria accompanying independence in the late 1950s and early 1960s, there has been a fundamental mismatch between the enormous potential for physical production in Africa and the capacity of Africans to achieve their economic aspirations. Table 1 shows that African states are poor and that life expectancy is low.

Africa's poverty is captured in a single statistic: the total GNP of the 45 countries in sub-Saharan Africa in 1985 was slightly less than the total GNP of Spain, a nation of 40 million (World Bank, 1987b). Sixteen of the 20 poorest countries in the world are African. Since 70% of the people in Africa live in rural areas, raising the income of rural people is a prerequisite for improving the African standard of living. Because poverty is the most central cause of hunger and malnutrition, it also follows that growth in per capita income is a primary way of helping families increase their access to food and reduce malnutrition.

African states are generally small in terms of population. Seventeen of the 40 countries in Table 1 have fewer than 5 million people, pointing up the need to examine how NARS in small countries can adopt what Emil Javier of ISNAR calls "intelligent borrowing" as the primary strategy for acquiring new technology. Intelligent and systematic borrowing of technology is the hallmark of the dynamic economic growth of Japan, Singapore, South Korea, and many other countries. Nevertheless, there is a widespread view in African scientific circles that Africa should develop its own technology rather than relying on borrowing technology as the primary source of acquiring new technology. For example, Professor Thomas Odhiambo, Director General of ICIPE forcefully argues that "Africa must outgrow its concentration on technology transfer as the primary mechanism for achieving agro-industrial development" (Odhiambo, 1987: 4).

Africa's economic crisis of the 1980s is first and foremost agrarian. And since the agrarian crisis in almost all African states is a failure of the food and agricultural sector, rather than simply a food crisis per se, the challenge for African policymakers and

Table 1. Economic Indicators for Forty Countries in Sub-Saharan Africa

	Population (millions)	GNP per Capita Annual Average Growth Rate		Agriculture Annual Average Growth Rate (Percent)		Average Index of Food Production per capita (1979-81 = 100)	Percentage of Labor Force in Agriculture		Life expectancy at birth (years)
	mid-1986	1986	1965-86	'65-'80	'80-'86	'84-'86	1965	1980	1986
Low Income		($)	(%)						
1. Chad	5.1	–	–	–	–	100	92	83	45
2. Guinea	6.3	–	–	–	0.3	93	87	81	42
3. Ethiopia	43.5	120	0.0	1.2	−3.9	87	86	80	46
4. Burkina Faso	8.1	150	1.3	–	2.7	112	89	87	47
5. Malawi	7.4	160	1.5	–	2.5	90	92	83	45
6. Zaire	31.7	160	−2.2	–	1.7	100	82	72	52
7. Guinea-Bissau	0.9	170	−2.0	–	0.3	–	–	–	39
8. Mali	7.6	180	1.1	2.8	−2.3	101	90	86	4
9. Mozambique	14.2	210	–	–	−15.9	85	87	85	48
10. Madagascar	10.6	230	−1.7	–	2.1	98	85	81	53
11. Uganda	15.2	230	−2.6	1.2	−0.1	111	91	86	48
12. Gambia, The	0.8	230	0.7	–	–	–	–	–	43
13. Burundi	4.8	240	1.8	3.3	1.3	98	94	93	48
14. Tanzania	23.0	250	−0.3	1.6	0.8	92	92	86	53
15. Togo	3.1	250	0.2	1.9	1.7	91	78	73	53
16. Niger	6.6	260	−2.2	−3.4	2.8	85	95	91	44
17. Benin	4.2	270	0.2	–	3.0	114	83	70	50
18. Somalia	5.5	280	−0.3	–	7.9	98	81	76	47
19. Central Afr. Rep.	2.7	290	−0.6	2.1	2.5	94	88	72	50
20. Rwanda	6.2	290	1.5	–	0.9	87	94	93	48

21. Kenya	21.2	300	1.9	4.9	2.8	87	86	81	57
22. Zambia	6.9	300	−1.7	2.2	2.8	96	79	73	53
23. Sierra Leone	3.8	310	0.2	2.3	0.5	97	78	70	41
24. Sao Tome/Principe	0.1	340	0.7	–	–	–	–	–	65
25. Sudan	22.6	320	−0.2	2.9	0.4	96	82	71	49
26. Lesotho	1.6	370	5.6	–	1.6	82	92	86	55
27. Ghana	13.2	390	−1.7	1.6	−0.2	109	61	56	54
28. Mauritania	1.8	420	−0.3	−2.0	1.2	88	89	69	47
29. Senegal	6.8	420	−0.6	1.4	2.3	102	83	81	47
Lower-Middle Income									
30. Liberia	2.3	460	−1.4	5.5	1.2	99	79	74	54
31. Cape Verde	0.3	460	–	–	–	–	–	–	65
32. Zimbabwe	8.7	620	1.2	–	3.4	92	79	73	58
33. Nigeria	103.1	640	1.9	1.7	1.4	103	72	68	51
34. Swaziland	0.7	690	2.8	–	–	–	–	–	55
35. Cote d'Ivoire	10.7	730	1.2	3.3	0.9	105	81	65	52
36. Botswana	1.1	840	8.8	9.7	−9.8	76	89	70	59
37. Cameroon	10.5	910	3.9	4.2	2.0	94	86	70	56
38. Congo, People's Rep.	2.0	990	3.6	3.1	−0.6	93	66	62	58
39. Mauritius	1.0	1200	3.0	–	5.3	100	37	28	66
Upper-Middle Income									
40. Gabon	1.0	3080	1.9	–	–	98	83	75	52

SOURCE: World Development Report (1988: Tables 1, 2, 7, and 31; Box A, p. 289).
– = Not available.

Figure 1. Countries and capital cities in sub-Saharan Africa

donors is to discover how to raise rural productivity and rural incomes across the board (Eicher, 1982a). The government of Kenya adopted this strategy in 1986 when it identified seven "essential" commodities that formed the core of its food and agricultural policy: maize, wheat, milk, and meat for food security; horticultural crops for both export and home consumption; and coffee and tea for raising farm income and earning foreign exchange. Kenya's approach is refreshing because it moves beyond the narrow debate on food and cash crops — a favorite among many PVO/NGO (private voluntary organizations/nongovernmental organizations) groups, and decides which commodities should be promoted in order to achieve multiple objectives, including family and national food security, foreign exchange, government revenue, employment, and regional balance.

The NARS in Africa are slowly replacing their food-centered research agenda of the 1980s with a more balanced research agenda — an agenda that focuses on the generation of new technology for food, livestock, and export commodities. Under conditions of rapid population growth, new technology is essential to help raise rural incomes, provide rural jobs, and assist in "parking a generation" of people in rural areas until fertility rates slow down and/or industrial expansion generates more jobs.

To summarize, Africa's economic crisis is complex and it has been building for several decades. Neither simplistic statements about changing the international economic order nor calls for export-led growth are the answers. The problem is rooted in the political neglect of agriculture during the colonial period. This neglect has continued in the post-independence period. Stop-gap measures have been tried - crash production campaigns and mass infusion of foreign aid - but these have mostly failed. Therefore, to meet the crisis, one must turn to agricultural-led growth. But, based on historical experience, an agricultural-led strategy must be framed in no less than a 20-year horizon and must entail a combination of technological innovation, policy reform, and institutional restructuring because each, by itself, is limited.

Institutions and African Development

With the exception of the pioneering research on institutional innovation by Vernon Ruttan and Yujiro Hayami, agricultural development specialists have neglected institutional issues. This has been especially true in Africa where social scientists have been enthralled with farming systems research, social impact assessment, and more recently, sustainable production systems. This lack of attention to research on institutions, however, does not come as a surprise. The late Gunnar Myrdal reports that when he was carrying out research for *Asian Drama* in the 1960s, the most difficult issue was learning how "to deal with the political issues of changing institutions, which were then, as now, avoided by most ordinary economists in their writings on development" (Myrdal, 1984: 154).

But the study of institutions has recently been moved to center stage by economists in industrial countries, such as Douglass North, Oliver Williamson, Irma Adelman, and many others. In a major 20-year investigation of the economic development process in 23 countries over the 1850-1914 period, two scholars recently concluded that "institutions mattered most in distinguishing between country groups experiencing more successful and less successful economic development" (Morris and Adelman, 1988: 209).[4] The authors concluded that "diversity in growth, diversity in institutions and diversity in applicable theories were the hallmarks of the process of nineteenth century development." Prof. Glenn L. Johnson of Michigan State University contends that "institutional limitations are presently the most serious constraining factor" for the agriculture of developed and newly industrializing countries and that the less-developed countries "are now constrained more by existing institutions and human capital stocks than by technologies and stocks of biological and physical capital" (Johnson, 1988: 1).

But research on rural institutions in Africa is in its infancy (Van Reenen and Waisfisz, 1988). The hard-core knowledge base on how to strengthen institutions such as NARS, extension services, and faculties of agriculture in Africa is inadequate.[5] Research is urgently needed on widespread institutional failure. But research is also needed on why some institutions are strikingly effective: the Kenya Tea Development Authority, serving 150,000 smallholders; the Zimbabwe smallholder Cotton Marketing Board; Botswana Meat Commission; West Cameroon Coffee Cooperative Union; and the Mali Sud Cotton Project that includes 50,000 smallholders (Abbott, 1987). These success stories should be carefully studied to draw lessons for institution building in the 1990s.

African states and donors are fumbling and confused about how to develop human capability and agricultural institutions at this early stage of African development. Many countries find it difficult to pursue long-term institution-building strategies because of civil unrest, political instability, and the ready availability of financial aid for overseas training and long-term advisors. In other countries, the real and imagined fear of political unrest constrains donors from pursuing the long-term institution-building models that were successful in Asia in the 1960s and 1970s. But the most fundamental issue is the inability of donors to come to grips with Africa's early stage of institutional and scientific maturity.

The longer one works in Africa, the more one is forced to conclude that the resource-transfer model of foreign assistance must be replaced by a human-capability/institution-building model of development. The shortcomings of the resource-transfer model are painfully apparent in Somalia. A recent joint UNDP/IBRD technical mission dug deeply into the mode of delivering foreign aid to Somalia, a country riven with clan wars and a century or two behind most Asian countries in terms of its level of scientific, institutional, and administrative maturity. The joint team reported that donors were collectively pumping US$ 100 million into Somalia each year to support 1200 expatriates on technical assistance contracts and overseas training for Somali nationals (UNDP and IBRD, 1985).[3] Nevertheless, this revolving-door model of foreign advisors and overseas training is not achieving the ultimate objective, "the development of national capacity through the permanent transfer of skills and know-how to Somali nationals and national institutions" (UNDP and IBRD, 1985: 2). Without question, the model is not addressing the long-term problem of developing sustainable Somali institutions.

Three decades of independence have produced a large knowledge base on why many foreign aid-financed agricultural and rural development projects are not performing well at this early stage of Africa's economic history and institutional fragility (Morss, 1984; Cernea, 1985, 1987; Zurek, 1985; World Bank 1987a, 1988d; Eicher, 1982b, 1984, 1988a, 1988b). There is consistent evidence that human capability and institutional barriers to development have been skirted in the drive to increase the flow of foreign aid to African agriculture – especially during the rapid build-up of aid for direct-action projects over 1973-83. Starting around 1983, the foreign aid pendulum shifted from project- to policy-based lending. But regardless of whether the focus was on projects or policies, the end result has been the same: the long-run human capability, scientific and institutional and social organizational issues – the prime movers of agricultural development – are being seriously neglected by both African policymakers and donors.[5] There is a need for a fundamental reexamination of the assumptions about Africa's stage of economic history, the differential levels of development of various African states, absorptive capacity, recurrent costs, and appropriate long-run strategies to strengthen national agricultural services such as research, extension, and training.

Institutional Development during the Colonial Period: 1930-1959

A skeletal agricultural research infrastructure was established in most countries in Africa during the first two to three decades of this century.[6] A few countries such as the Sudan launched research programs immediately following World War I (Idris, 1969). By 1930, a small group of researchers was at work in most countries. Most researchers focused on export commodities, but research on food crops included sorghum in Uganda, maize in Zimbabwe and Kenya, rice and cassava in Zaire, and rice in anglophone and francophone West Africa.

Without question, many national agricultural research systems (NARS) in Africa were effective producers of new technology during the colonial period. The creativity of NARS can be illustrated through historical sketches of research in Zaire, Zimbabwe, and Kenya over the 1930-59 period. In Zaire, formerly the Belgian Congo, about two-thirds of the budget of the Belgian-financed national agricultural research service – INEAC – was focused on export crops and one-third on food crops. Research on oil palms was launched in 1933 with the goal of developing a high-yielding palm to replace the tall, low-yielding, wild palm that grew in the bush in West and Central Africa.[7] In 1939, after only six years of research at the INEAC station at Yangambi in northern Zaire, a small team of *five* researchers unlocked the genetics of the oil palm, leading to the development of hybrid varieties that out-yielded wild palms by several hundred percent under farm conditions (Bevinaert, 1940; Tollens, 1988).

The oil palm research at INEAC had large regional and international spillover effects which helped launch the modern oil palm industry in Cote d'Ivoire (formerly the Ivory Coast),[8] Nigeria (Eicher, 1967), Malaysia (Hartley, 1970), and Indonesia.

INEAC's rice research also demonstrates the spillover effects of a technology-producing national agricultural research system (TP/NARS). In 1958, INEAC released an upland rice variety, O.S.6, after six years of breeding and testing while relying on one of the first mainframe computers in Africa to process the experimental data.[9] Although O.S.6 is not grown in Zaire, it is one of the dominant upland rice varieties in West Africa some 30 years after its release. O.S.6. is grown under different local names in West Africa today and it accounts for about 90% of the upland rice grown in Nigeria. In summary, the INEAC research program in Zaire illustrates the vast potential that national research services in Africa have for producing new technologies for food and export crops and for contributing to meeting the research needs of neighboring countries and the global agricultural research system.[10]

The NARS of Zimbabwe is the second example of the creativity of a national system in Africa. Hybrid maize development in Zimbabwe from 1932 to 1960 represents a textbook example of a NARS in Africa producing new technology without relying on imported germplasm.[11] In 1932, H.C. Arnold launched a maize improvement program in Zimbabwe (then Southern Rhodesia). In 1938, A.G.R. Rattray assumed the leadership of the program, and in 1949, 17 years after research was initiated, the first hybrid, SR-1, was developed by crossing two locally bred open-pollinated varieties, Southern Cross and Salisbury White. But SR-1 was not released to farmers because yields were low. Research continued from 1949 to 1960 in a search for higher-yielding hybrids. In 1960, SR-52, a single-cross hybrid was released to commercial farmers after 28 years of research (1932-1960). Looking back over the past six decades of research on food crops in Africa, the SR-52 white maize hybrid is undoubtedly the Green Revolution food-crop success story in Africa (Eicher, 1984, 1986). Historically, the size of the maize research program in Zimbabwe has been small (two to four researchers), but the program is known for its continuity, its scientific and administrative leadership, and its productivity.[12] Zimbabwe's experience also illustrates the extensive spillover effects of a TP/NARS. SR-52 maize has been sold as far north as Ethiopia, as far west as Cameroon, and as far south as the Republic of South Africa.

In Kenya's national agricultural research system, it took Michael Harrison and his maize team only nine years (1955-1964) to develop a high-yielding hybrid maize variety by crossing a local variety with a variety imported from Ecuador. Kenya's experience illustrates the potential of importing germplasm and underscores the need for the NARS in Africa to develop a high level of technical capacity to pursue a strategy of "intelligent borrowing" of technology from neighboring countries and the global system.

Regional research institutions were introduced during the colonial period from 1930 to 1959 to deal with the problem of small countries and to stimulate the production of export crops for European markets. One of the most successful regional research and extension projects in Africa is the CFDT/IRTC network that supports smallholder cotton production in 10 countries in francophone West Africa. Cotton research is carried out by IRTC[13] researchers in France, Cote d'Ivoire, and satellite countries in francophone West Africa. The CFDT[14] is a private cotton management and extension organization with four decades of experience in West Africa. In nine of the 10 francophone countries where data are available, average cotton yields increased fourfold over the 20-year period, 1963-1982 (Dequecker, 1983). The World Bank recently evaluated the CFDT/IRTC cotton model in Burkina Faso, Cote d'Ivoire, and Togo and concluded that it is a "striking success" when compared with other agricultural development projects in Africa (World Bank, 1988b: 29). Lele and van de Walle (1988) recently concluded that phasing out regional cotton programs in anglophone Africa in the 1970s explains the slow growth in cotton production in anglophone relative to francophone Africa over the past 15 years.

In anglophone West Africa, the colonial period from 1930 to 1959 was marked by constant experimentation with research models to deal with the small country problem (Kyomo, 1988). In 1930, Ghana was the world's largest cocoa producer, but the industry was plagued by insect and disease problems. To deal with these problems, a National Cocoa Research Institute was established at Tafo, Ghana, in 1938 by the British Colonial Service. The Institute carried out highly successful studies of controlling several cocoa diseases, including swollen shoot virus, capsid, and black pod. In 1946, spraying programs based on research findings were launched and they were instrumental in boosting Ghana's cocoa production to a peak output of 520,000 tons in 1965 (Martinson et al., 1987). In 1944, the Cocoa Research Institute was renamed the West African Cocoa Research Institute (WACRI) and given a mandate to serve both Ghana and Nigeria. But cocoa research in Ghana over the past 50 years is marked by constant organizational change and turmoil:

- 1938 – Cocoa Research Station established at Tafo to serve Ghana.

- 1944 – West Africa Cocoa Research Institute (WACRI) replaced the Cocoa Research Station with a mandate to serve Ghana and Nigeria.

- 1962 – Five years after independence, the government of Ghana dissolved WACRI and set up the Cocoa Research Institute of Ghana (CRIG). The government of Nigeria then converted the WACRI station to the Cocoa Research Institute of Nigeria (CRIN).

- 1975 – The mandate of CRIG was expanded in 1975 to include coffee, kola nuts, and shea nuts.

Cocoa research in Ghana has also been subjected to constant change in parent organizations. Since 1962, cocoa research in Ghana has been administered by the following six organizations in chronological order:

- National Research Council;

- Ghana Academy of Sciences;

- Council for Scientific and Industrial Research (CSIR);

- Ministry of Cocoa Affairs;

- Ghana Cocoa Marketing Board;

- Ghana Cocoa Board.

Three lessons have emerged from 50 years of cocoa research in anglophone West Africa. First, the colonies of Ghana and Nigeria were well served by a small team of British scientists in a highly productive regional research institute (WACRI) from 1944 to 1962. In 1944 WACRI was staffed with 15 British scientists. Second, the transition from a regional (WACRI) to a national research model (CRIG) in 1962 led to a breach in research continuity because 12 expatriate staff resigned, leaving seven professional staff and 25 vacancies at the Cocoa Research Institute of Ghana (CRIG).[15] CRIG is now nationalized but it is starved for operating funds and it has poor linkages with the cocoa extension service.[16] It is now negotiating with the Overseas Development Administration (ODA) of the United Kingdom for a US$3.1 million grant for research support as part of a five-year multidonor cocoa rehabilitation project. The third lesson is that the research management of NARS suddenly emerged as a critical factors when the regional institutes were nationalized. For example, the management of cocoa research in Ghana has been in constant turmoil since CRIG was nationalized in 1962. No scientific organization can flourish as it passes from one ministry and agency to another on the average of once every three years as CRIG has done since 1962.

Just as Ghana was the world's largest cocoa producer during the colonial period, Nigeria was the leading producer of oil palm. In 1939 the British colonial government established an Oil Palm Research Station in Nigeria in order to meet the growing challenge of oil palm production on plantations in the Far East. In 1951, the British converted Nigeria's oil palm station into the West African Institute for Oil Palm Research (WAIFOR) at Benin City, Nigeria, with a mandate to serve the British West African territories of Nigeria, Ghana, Sierra Leone, and Cameroon. In the 1950s, WAIFOR had a scientific staff of only 16 senior officers (Table 2). Soon after Nigeria became independent in 1960, the new government decided to nationalize WAIFOR and rename it the Nigerian Institute for Oil Palm Research (NIFOR). During the 1962-64 transition period, 10 of the 15 research officers left the institute. When NIFOR was formally established in 1964, it had a staff of 10 senior officers (five of whom were on overseas training), and the number increased slowly to 15 by 1970. But Nigeria's oil boom of the 1970s provided funding to increase NIFOR's staff from 15 senior officers in 1970-71 to 283 in 1985.

Today, the Nigerian Institute of Oil Palm Research (NIFOR) is not performing well. A very substantial part of NIFOR's budget is used to pay the salaries of its vast administrative, scientific, and support staff. Only about one-third of its regular staff are directly engaged in research while the other two-thirds are in administration, support services, social services, and revenue generating activities. For example, in

Table 2. Number of Senior and Junior Officers at the West African Institute for Oil Palm Research (WAIFOR) and the Nigerian Institute for Oil Palm Research (NIFOR), 1955 to 1988

Type of Staff	WAIFOR 1955	WAIFOR 1963	NIFOR[1] 1964	NIFOR 1970	NIFOR 1985	NIFOR 1988
Senior Officers	16	15	10[2]	16	283	289
Junior Officers and (Technicians)	153	151	204	357	1,487	1,471
Total Regular Staff[3]	169	166	214	373	1,770	1,760

SOURCE: West African Institute for Oil Palm Research (1955/56, 1963), Nigerian Institute for Oil Palm Research (1965–65, 1969-70, 1970-71, 1985) and personal interviews, January 1988.

1. In 1964 WAIFOR was nationalized and became known as NIFOR.
2. Five of the 10 officers were on overseas training.
3. Excludes unskilled seasonal laborers.

1985, 48 scientists were working on the key crop – oil palm – while 64 out of the 283 senior officers were administering the institute. NIFOR is also starved for foreign exchange to purchase equipment and supplies. Its research mandate has been broadened beyond oil palm to include date palm, raphia, coconut, and other palms. In summary, NIFOR is top-heavy with administrative staff, and it is less productive today with 289 senior officers than it was when it had only 15 during 1955-1970. The sobering lesson that flows from cocoa and oil palm research in West Africa is that there is no guarantee that simply increasing agricultural research expenditures and the number of scientific staff will lead to greater research productivity. This is an important message for African politicians, research managers, and donors. But most donors have a strictly ahistorical view of development and they lack an institutional memory.

The rise and decline of cocoa and oil palm research in Ghana and Nigeria stands in sharp contrast to the experience of Malaysia and Indonesia. In 1925 Malaysia established the Rubber Research Institute of Malaysia (RRIM) and concentrated its national research effort on rubber for four decades. Malaysia became independent in 1957, the same year as Ghana, but today Ghana's per capita GDP of $390 stands in sharp contrast to $1,830 in Malaysia. In the late 1960s, Malaysia embarked on a massive agricultural diversification program away from rubber, with the goal of increasing rural incomes. Policymakers assumed that Malaysia had a long-term comparative advantage in producing a wide range of export crops such as oil palm and cocoa and that foreign exchange earnings from these crops could be used to finance food imports such as rice. To further its diversification of export crops, in 1969 the government decided to broaden its national research effort beyond rubber and it established the Malaysian Agricultural Research and Development Institute (MARDI), which began operations in 1971. Malaysia drew on Zaire's research on hybrid palms (Beirnaert, 1940) and over time developed hybrids for Malaysian conditions. In 1978, oil palm research was spun off from MARDI into a new institute, the Palm Oil Research Institute of Malaysia (PORIM) (PORIM, 1985). Malaysia is also planning to spin off cocoa research from MARDI and set up a separate cocoa research institute with the goal of around 100 scientists and technicians. It has increased its agricultural research staff from 100 officers at independence in 1957 to 1,000 today. Its research system is highly productive and it has helped Malaysia increase export crop production and world market shares.[17]

But West Africa – especially Nigeria – has dissipated its research base for oil palm and cocoa, and lost world market shares to Malaysia and Indonesia. For example, oil palm production is booming in Malaysia and Indonesia and planners in these countries no longer take West Africa as a serious competitor in the world oil palm trade. The dominance of Indonesia and Malaysia in world oil palm production is shown in 1986 production data:

Cote d'Ivoire	195,000 MT
Nigeria	550,000 MT
Indonesia	1,274,000 MT
Malaysia	4,500,000 MT

But restoring West Africa's competitive position in oil palm and cocoa research will require more than financial assistance from donors. Many basic political, organizational, managerial, and scientific questions are plaguing export-crop research in West Africa. These problems must be addressed first and foremost by Africans at both the political and scientific levels.

Five lessons for agricultural research policy in Africa flow from the colonial research experience:

1. Creativity of technology-producing NARS (TP/NARS)

During the colonial period, numerous countries demonstrated that national agricultural research systems could produce new technology and contribute to the global research system, rather than simply borrowing technology along the lines of the international technology-transfer model. A strategy to strengthen NARS in Africa in the 1990s should start with the premise that TP/NARS are a fact of life. Donors should agree on making strategic investements in eight to 10 TP/NARS over the next 30 years. But this does *not* mean pumping $20 million to $30 million into a TP/NARS over the next five to seven years. Rather, the challenge will be in spreading $20 million to $30 million in a NARS over the next 20 to 30 years with the aim of strengthening the quality of the research programs, improving financial mangement, and developing political and financial support from national sources.

2. Small commodity-research teams

In most cases, three to four scientists, and in a few cases, no more than half a dozen scientists, formed the commodity teams of TP/NARS that produced hybrid maize in Zimbabwe and Kenya, rust-resistant wheat in Kenya, improved tea clones in East Africa, cotton in Uganda, and soybean and cotton varieties in Zimbabwe. But this "focus-and-concentrate" strategy was not been heeded in the first 30 years of Africa's independence. Instead, the overarching goal of most NARS has been a) to expand the number of commodity research programs, b) to expand downstream research (e.g., farming systems research), c) to increase the number of scientists, technicians, and total staff, often at the expense of the overall quality of the NARS research program, and d) to expand the number of nonresearch activities such as managing plantations and processing plants and selling seedlings. For example, even though Nigeria has 1,000 agricultural scientists in 1988, its NARS is weaker today than when it had 100 scientists at the time of independence in 1960.

3. Research spillovers: Regional, pan-African, and international

Research spillovers from TP/NARS and regional institutes are illustrated by hybrid oil palm, hybrid maize, cotton, and many other commodities. For example, Cote d'Ivoire, Nigeria, Malaysia, and Indonesia borrowed the research on oil palm genetics from Zaire. Because spillover effects are common features of national, regional, and international research centers, donor projects to strengthen NARS in Africa should explicitly address this issue in project documentation and implementation.

4. Technology-borrowing NARS (TB/NARS)

The colonial experience is documented with success stories of borrowing technology. For most countries in Africa today - especially the 22 countries with less than five million people - intelligent borrowing of technology will be the primary strategy for acquiring new agricultural technology for the foreseeable future. But it will be necessary to convince African scieatists that borrowing technology is not a second-rate, demeaning activity, and that it takes a high level of technical competence to develop an efficient national capacity to borrow, test, screen, and adapt technology to micro environments.

5. Regional research: Efficient but unsustainable

Regional research in anglophone Africa during the colonial period was highly efficient because it concentrated on a few commodities, had assured overseas funding, and was endowed with outstanding administrative and scientific leadership. Examples of successful regional research include the East African Agricultural and Forestry Research Organization (EAAFRO) in East Africa; the Federation of Northern Rhodesia (now Zambia), Southern Rhodesia (now Zimbabwe), and Nyasaland (now Malawi); and the West African commodity research institutes (cocoa, oil palm, rubber, rice). But with the coming of independence in the late 1950s and early 1960s, the regional centers were converted into national institutes which came under political pressure to absorb staff, especially recent university graduates.

In francophone West Africa, several impressive regional research networks are still in operation, such as the IRCT/CFDT cotton research and extension network (World Bank, 1988b). Nevertheless, although regional research institutes represent an efficient research model, they are generally *not* financially sustainable from African sources. The Tea Research Foundation of Central Africa is one of the few examples of an African-financed regional institute but it has a small staff and it has turned to donors for support over the past decade (Ellis, 1988).

Institutional Development during the Post-Independence Period: 1960-1988

The collective experience of restructuring and strengthening rural institutions in the first three decades of independence can be analyzed under five topics:

1. The colonial legacy

At independence, African states inherited a strong bias for extension and international technology transfer to accelerate agricultural growth. This bias was based on the colonial premise that culture-bound, small farmers needed to be educated and motivated, and that foreign assistance could be used to rapidly expand the number of low-paid extension agents relative to more highly paid agricultural researchers. With some rare exceptions, at independence the institutional base – training, extension, and research – for African agriculture was geared to supporting export agriculture, large farms, plantations, and ranches. This was a fact of life in 1960 when 17 countries won their independence, in 1975 when Mozambique and Angola won their independence, and in 1980 when Zimbabwe won its independence with a government to serve the rural majority – 700,000 black smallholders, as well as 5000 commercial farmers.

Over the past 30 years, only modest progress has been achieved in converting the land-tenure, training, and research institutions to support the majority of rural people. For example, the government of Senegal waited until 19 years after independence to set up a BSc-level training program in agriculture in 1979 (Eicher, 1982a). Tanzania and Ethiopia have only recently established state agricultural universities. Zimbabwe's land-settlement program is stalled after settling about 40,000 families between 1980 and 1988 (instead of the planned 162,000 families between 1982 and 1985). In summary, the basic restructuring of agrarian institutions to serve the majority of rural people is proceeding at a snail's pace in most African countries. It comes as no surprise that project aid and structural adjustment lending all but ignore these festering institutional realities.

In many parts of Africa, the case can be made that the vast outpouring of foreign aid has helped maintain the status quo and postponed the inevitable restructuring of agrarian institutions and the domestic financing of basic agricultural services, such as NARS and training institutions. For example, donors are paying for a large share of the national research budget in a number of African countries, including Senegal. Prof. John Lewis of Princeton University reports that Senegal's annual, official, development assistance of over US$ 50 per capita is four or five times higher than per capita levels for Asian aid recipients. In macro terms, Lewis reports that "foreign aid paid for all of Senegal's investments and 6% of its consumption in 1981" (Lewis, 1987: 285). With this level of generosity, why should administrators of Senegal's national agricultural research, extension, and training institutions allocate their energy to generating political and financial support from Senegalese clientele groups?

Table 3 presents data on the stock of human capital – Africans and expatriates in NARS and universities in sub-Saharan Africa – that has been patiently compiled by ISNAR researchers, Phil Pardey, Han Roseboom, Howard Elliott, and many others (Pardey et al., *in press*). The table shows that anglophone countries such as Nigeria, Kenya, and Ghana have achieved substantially greater progress in the nationalization of their NARS, relative to francophone countries. For example, Cote d'Ivoire and Nigeria have been independent for the same length of time. But after 28 years of independence, Cote d'Ivoire has 73% of its research and teaching posts filled by expatriates, compared with 6% in Ghana and none in Nigeria. This is a puzzle that warrants further analysis and debate at the political and technical levels.

2. *Destruction of regional, national, and local institutions*

The 1960s and 1970s were marked by intense destruction of many of the regional and national institutions inherited from colonial governments. For example, most of the regional research institutes in anglophone Africa, such as the West African Cocoa Research Institute and EAAFRO, were converted into national institutions soon after independence (Dagg, 1986). At the national level, many colonial institutions were abolished. Guinea and Madagascar terminated the services of French researchers soon after independence, and in 1962, Nkrumah abolished Ghana's national extension service. The government of Tanzania abolished local government and farm cooperatives in the mid-1970s. Numerous training institutions, such as Makerere University in Uganda, were devastated during internal political upheavals. Many of the state institutions that were set up to serve farmers, such as marketing boards, have in fact "turned against them" (Arhin et al., 1985).

The influential Berg Report of 1981 recommended a shift to market liberalization and a reduction in public-sector employment (World Bank, 1981b). Because of the economic crisis in the early 1980s, African governments were belatedly forced to reexamine the role of public institutions and state control over agriculture. This is now a time of reflection and reexamination in Africa. Former President Nyerere of Tanzania recently reported that "there are certain things I would not do if I were to start again. One of them is the abolition of local government and the other is the disbanding of cooperatives. We were impatient and ignorant" (Nyerere, 1984). Tanzania has recently reintroduced local government and cooperatives.

Without question, one of the underreported events limiting African agriculture is the cycle of destruction of human capital because of coups, civil wars, and civil unrest. At least a half dozen countries have been stripped of high-level human capital through

Table 3. Sub-Saharan Africa: Total Number of Agricultural Researchers in National Agricultural Research Systems and Universities, Qualification Indices and 1980–86 Averages

	Number of Agricultural Researchers				Qualification[1] Index: Total (percent)	Qualification[1] Index: Nationals (only) (percent)
	Total	Local	Expat.	Expat. (%)		
WESTERN AFRICA						
Benin	45	42	3	(7)	73	71
Burkina Faso	114	59	55	(48)		
Cameroon	187	126	61	(33)		
Cape Verde	16	13	3	(19)	57	45
Chad	28	20	8	(29)		
Cote d'Ivoire	201	54	147	(73)		
Gambia	62	45	17	(27)		
Ghana	138	130	8	(6)	74	69
Guinea	177	NA	NA			
Guinea–Bisau	8	7	1	(13)	75	71
Liberia	33	24	9	(27)	69	57
Mali	275	246	29	(11)	29	20
Mauritania	12	NA	NA		92	
Niger	57	25	32	(56)		
Nigeria	1005	NA	NA			
Senegal	174	123	51	(29)		
Sierra Leone	46	NA	NA			
Togo	49	37	12	(24)		
Subtotal	2626			(31)[2]	50[2]	29
CENTRAL AFRICA						
Burundi	53	30	23	(43)	85	73
Central African Rep.	NA	NA	NA			
Congo	68	37	31	(46)		
Gabon	24	10	14	(58)	71	30
Rwanda	34	24	10	(28)		
Sao Tome & Principe	3	NA	NA			
Zaire	43	NA	NA		23	
Subtotal	225			(43)	60	59

Table 3. (continued)

	Number of Agricultural Researchers				Qualification[1] Index: Total (percent)	Qualification[1] Index: Nationals (only) (percent)
	Total	Local	Expat.	Expat. (%)		
SOUTHERN AFRICA						
Angola	28	15	13	(46)	46	0
Botswana	50	22	28	(56)	73	38
Lesotho	18	9	9	(50)	67	33
Madagascar	83	73	10	(12)	48	40
Malawi	80	75	5	(6)	30	26
Mauritius	99	NA	NA		36	
Mozambique	77	13	64	(83)	83	0
Swaziland	11	7	4	(36)	44	17
Zambia	111	57	54	(49)	61	24
Zimbabwe	153	NA	NA		45	
Subtotal	710			(41)	52	24
EASTERN AFRICA						
Comoros	14	7	7	(50)	50	0
Ethiopia	142	134	8	(6)	43	40
Kenya	483	408	75	(16)	45	
Seychelles	7	4	3	(38)	38	0
Somalia	31	27	4	(13)	9	
Sudan	206	NA	NA		81	
Tanzania	276	214	62	(22)	61	49
Uganda	185	NA	NA			
Subtotal	1343			(17)	54	44
TOTAL SUB-SAHARAN AFRICA	4905			29	53	38

SOURCE: Pardey and Roseboom (*In press*).

1. Calculated as (number of PhD + MSc researchers)/(total number of researchers). For the qualification index based on the total number of researchers (national + expatriate), the expatriate researchers were assumed to hold either a PhD or MSc (or equivalent) qualification.

2. Subtotal figures are weighted group averages, where the weights represent the proportion of total agricultural researchers for each regional group accounted for by each country.

outmigration over the past three decades. Ghana, Ethiopia, Uganda, Somalia, Tanzania, and Zambia are prominent examples. Emil Rado recently reflected on the international brain drain in Ghana: "Ghana does not lack people of the highest capability. But the flower of them is abroad, in self-imposed exile. The PNDC (ruling party) has yet to face squarely the task of so broadening its constituency that it can attract them back" (Rado, 1986).

3. *The quantity-quality trade-off*

Thirty years of independence have been dominated by an unbridled growth in the size of the civil service, national agricultural research and extension services, and parastatals. Most nations (with substantial donor encouragement) opted to increase the size of key institutions such as NARS and extension services. The following figures display the quantum jump in the size of the state machinery:

- Sub-Saharan Africa started independence with a profound extension bias (21,200 extension agents and 1,329 researchers), and this bias was intensified by hiring an additional 36,000 extension agents over the next 20 years (Judd et al., 1987: 11-13).

- The Congo increased the size of its extension staff 10-fold from 1960 to 1972 (Young, 1988: 26).

- The Senegalese government employed 10,000 persons at independence in 1960 and 61,000 in 1978 (Young, 1988: 27).

- In Ghana, the Cocoa Marketing Board employed 105,000 persons in the early 1980s to handle a crop half as large as that which 50,000 employees had managed in 1965 (Young, 1988: 27).

- In Nigeria, the national agricultural research service expanded from 100 researchers in 1960 to around 1000 today (Table 2).

But in most cases, there was a clear trade-off in quantity versus quality and the expansion of size was accompanied by a reduction in the quality of the enterprise – whether it was the civil service or a NARS (Lipton, 1988). The major lesson for most NARS in the 1990s is to freeze and/or reduce the total number of employees and concentrate on improving the quality of scientists and their research programs and replacing expatriates in the process.

4. *The Green Revolution footprint*

The Green Revolution has achieved the impact of a small footprint on Africa's rural landscape. Dalrymple (1986a, 1986b) reports that the total area of modern wheat and rice varieties under cultivation in sub-Saharan Africa in 1983 was about 800,000 ha (wheat 556,000 ha and rice 242,000 ha), which amounts to roughly one-quarter of the annual cropped area in Zimbabwe, one of the 45 countries in Africa.

5. *The imperative to strengthen NARS*

Since the Green Revolution has barely touched Africa, African leaders and the donor community must face up to the reality that the CGIAR and French research networks have not delivered the volume of new food crop technology that many experts had implicitly promised when the first CGIAR center – IITA – was established in Ibadan some 20 years ago. Therefore, African states, agricultural scientists, and donors are compelled to face up to the question: what can be done to strengthen NARS in a cost-effective and sustainable manner so that they can become more productive partners in producing new technology and complementing the CGIAR and French research systems?

In summary, the post-independence experience from 1960 to 1988 displays consistent evidence that the dominant institutional and technical assistance models of donors[18] are not producing the expected increase in agricultural output in Africa, except in a few middle-income countries such as Zimbabwe. For example, donors are pumping US$ 100 million a year into Somalia to finance 1,200 long-term expatriates and overseas training through a foreign-assistance model that postpones the tough issues surrounding the development of Somali institutions. Turning to the Sahel, the former director of the Club du Sahel, Anne de Lattre, recently reported that the targets for the recovery of the Sahel are not being achieved despite the receipt of US$ 15 billion of foreign assistance over the past 13 years for the 36 million people in the Sahel (de Lattre, 1988).

Although many donors are reluctant to publish the results of their evaluations, it is well known that the failure rate of rural projects is high.[19] For example, the World Bank's Operations Evaluation Department recently evaluated the Bank's experience with financing rural development (RD) projects from 1965-1986 and noted that although "RD lending targets were met, . . . half of the RD projects in sub-Saharan Africa failed" (World Bank, 1988d: xvi). The training and visit extension system (T & V) is being aggressively promoted by the World Bank in Africa. Preliminary evidence suggests that the T & V model may be sustainable in high-potential farming areas such as the central highlands of Kenya, but not in sparsely populated semi-arid areas. Because of the Bank's zealous promotion of the T & V approach,[20] continuing independent assessments of on-going T & V programs would be in Africa's self-interest.

Most African states do not currently have the institutional, managerial, or financial capacity to absorb present levels of project aid "with integrity" and to sustain the projects after foreign aid is phased out.[21] In some subregions, such as the Sahel, foreign aid officials no longer discuss the "recurrent cost problem" because it is assumed that donors will be paying some of the operating costs of Sahelian governments for the indefinite future – perhaps for another generation or longer.[22]

Longer-Term Issues to Ponder: 1990-2020

Drawing on Africa's research experience over the past 60 years, six strategic issues emerge for debate on strengthening the institutional base for African agriculture over the next 30 years.

1. Restoring the primacy of commodity-based research

During the colonial period, long-term, highly focused research on a single crop such as cotton, groundnuts, cocoa, oil palm, or maize was successful in producing new technology that was relevant to African conditions.[23] But many NARS and donors have ignored this experience and have spread their support for research over too many commodities, too many discrete projects, and too broad a geographical area. For example, until 1985, USAID was supporting research on 28 commodities in Africa, but it has subsequently reduced the number to eight (USAID, 1985). A World Bank-financed project in Rwanda endorsed research on 17 commodities. In some countries over the past decade, farming systems research (FSR) has been given priority over commodity research. But FSR is now in decline as African research administrators seek to find a better balance between commodity and farming systems research. The key questions are striking the proper balance between the number of commodity and FSR scientists, budget allocation to commodity and FSR programs, and sequencing. FSR should serve as a handmaiden (servant) to commodity-research teams (Eicher, 1987). A strategic priority in the 1990s is strengthening national commodity-research teams on a few priority commodities. In some countries this will be only one staple food, while in others it may be three or four commodities.

2. Agricultural research investment norms and priorities

The second issue concerns how much African states should spend on agricultural research? Presently, most donors follow the guideline that a desirable agricultural reseach investment target would be in the range of 0.5% to 2.0% of the total national value of agricultural GPD. The World Bank has argued that a desirable investment target for research for many countries would be an annual expenditure (recurrent, plus capital) "equivalent to about 2 percent of agricultural gross domestic product" (World Bank, 1981a: 8). But this norm is derived from industrial countries with a century or more of experience in mobilizing political and financial support from farm organizations, commodity groups, private firms, and state and federal organizations. Foreign aid metered out to NARS in Africa according to the 1% to 2% investment norm will most likely inflate the size of the NARS (staff, buildings, and equipment) beyond the capacity to mobilize domestic political and economic support to maintain NARS over time.

When donor funds are transferred to a NARS in Africa according to the 1% to 2% formula from industrial countries, the missing elements in this resource transfer are the "political will and political support" from agricultural interest groups that have been nurtured by research managers and scientists over generations in industrial countries. Prof. Vernon Ruttan (1987) has repeatedly stressed the need to tie incremental donor funding for NARS to matching funds from the recipient government. The failure to follow some variant of matching funding increases the likelihood that donor funds may increase the size of NARS beyond the political will to maintain the system. The spectre of Mali's 275 agricultural scientists is a case in point.

In summary, the agricultural research investment norms derived from the experience of advanced countries, either capitalist or socialist, are almost certain to be inappropriate short-term policy guides for donors and for African states. Despite 60 years of organized agricultural research in Africa, there is little solid information on the economics of research in Africa. No published studies are available on the economic returns on investment in any commodity or in any NARS in Africa.[24] A series of case studies is needed on the economics of investment in agricultural research in Africa.

3. *Size, quality, and productivity of NARS*

There is little solid empirical information from Africa on the relationship between the size (number of scientists), quality of scientific staff, and productivity of a NARS. There is, however, enough historical and anecdotal evidence to conclude that some of the pronouncements on the level of investment and the size of NARS in Africa should be taken with a grain of salt. For example, Jha (1987) recently studied national agricultural research systems in Africa and concluded that there is "substantial underinvestment" in agricultural research because 14 countries were spending less than 0.5% of their agricultural GDP on research (Jha, 1987: 267). Instead of coming to Jha's conclusion, one can make a convincing case that there is overinvestment in research in some countries relative to their current stage of institutional maturity, absorptive capacity, scientific leadership, political support for research, and projected government revenues.

Three examples reinforce this point: First, most African countries have ignored the colonial experience of high payoffs to small research teams and have expanded the size of their NARS in terms of the number of scientists, technicians, buildings, equipment, and operating budgets. In many cases this expansion has outstripped the capacity to manage the national research enterprise, pay staff on time, plant experiments on schedule, and mobilize political support to finance and sustain the system after foreign aid is phased out. Under the current levels of foreign aid in Africa, it is often easier for the director general of a NARS to mobilize an additional million dollars of research support from foreign donors than it is from domestic funds. This illustrates how foreign aid can increase the dependency on foreign donors and postpone the day of reckoning.

Second, donors are part and parcel of the drive to increase the size of NARS. For example, donors are currently paying a substantial share of the recurrent budget of the national agricultural research systems in Mali, Ghana, Senegal, Niger, Zambia, Rwanda, and many other countries. It is almost impossible to cite a feasibility study that recommends reducing the size of a NARS and concentrating on upgrading the quality of the present research staff and the relevance of the research programs.

Third, many NARS have been under political pressure to absorb new university graduates and expand the size of the institution at the expense of quality. For example, Nigeria has invested at a brisk pace in expanding its National Agricultural Research Service from around 100 scientists at independence in 1960 to 1000 in 1988 (Table 2). But Prof. Francis Idachaba, Vice-Chancellor of the University of Agriculture, Makurdi, Nigeria, recently reported that "research management probably constitutes the most important constraint on Nigeria's National Agricultural Research System" (Idachaba, 1987: 351).

In summary, many African countries are making some of the same mistakes that Asian and Latin American countries made in the 1970s when the emphasis was placed on expanding the size of NARS to the point where there were too many research facilities and researchers "without" programs (Ruttan, 1987: 78). There is need for a study of the size, productivity, and sustainability of NARS and the economies of agricultural research.

4. The training fallacy

Many African states, donors, and members of the university community maintain that more training is needed to solve Africa's shortage of skilled manpower. But this standard prescription has been overtaken by events in many countries where the human resource problem has shifted from the supply to the demand side as recent agricultural graduates at the certificate, diploma, and higher levels have found it increasingly difficult to find jobs. In addition, many NARS and universities in Africa are hemorrhaging and losing scientists and teachers as fast as they are trained. For example, the average loss of NARS research officers with a university degree is estimated to be about 7% per year (World Bank, 1988c: 18), a rate that would require a NARS to replace its entire cadre of researchers every 13 years. Another serious problem is the loss of productive scientists and teachers over 40 years of age. Four guidelines for training in the 1990s are as follows:

- NARS and faculties of agriculture should utilize a systems approach in developing a human resource strategy that includes recruitment, training, promotion, and retention of researchers and teachers.

- The number of researchers and teachers released for training should be tailored to the ability of the country to finance and sustain them over the long pull.

- Training should concentrate on a) upgrading present staff and b) replacing expatriates rather than training to fill new posts and increase the size of the organization.

- Faculty of agriculture expansion projects should be designed within a subregional perspective (e.g., the Sahel) to avoid duplication of training facilities.

5. *The need for rolling subregional research maps*

Africa's immensity and diversity rule out any meaningful discussion of Africa-wide research priorities and guidelines for strengthening NARS. There is a compelling need for African research managers and donors to adopt a subregional geographical area such as the Sahel or Eastern Africa as the operational unit for developing research strategies and a framework for considering investments in NARS, regional institutes (e.g., WARDA), and regional research networks. The present method of preparing feasibility studies for NARS on a country-by-country basis ignores research spillovers from NARS to neighboring states and regional and international centers. By ignoring these spillovers, there is a high probability that donors will overinvest in NARS and contribute to the inflation of NARS in terms of size.

The practical message that flows from this discussion is the need for an organization such as ISNAR to develop rolling regional research maps to guide teams that are preparing feasibility studies for donor investment in NARS. Subregional research maps should contain a vision of the long-term dynamic comparative advantage of agriculture in a sub-region, identification of present research institutions and donor activities (present and projected) and research priorities to help change the comparative advantage of agriculture in a subregion over time. It is important that the preparation of research maps should not lead to research inventories that count all the research projects in a region such as the Sahel (Devres, 1984) or Southern Africa (Devres, 1985).

6. *Sustainability of NARS*

A sustainable NARS has been defined as one that has the ability to mobilize domestic political support to pay the salaries and required operating costs of the core scientific staff from national sources. Presently, the complex issues surrounding the sustainability of NARS are not being systematically addressed by any major donor or international institution working in Africa.

Reflections on the World Bank's Strategy to Strengthen NARS in Africa

Donors are an integral part of Africa's agricultural research dilemma. For example, the development of sustainable African institutions is being undermined by the decision of donors to use lower standards of performance in evaluating investments in Africa. Edward Jaycox, Vice-President of the Africa Department of the World Bank recently pointed out that:

> Donors have continued to prefer new investments long after it became clear that budget revenues would be inadequate even to maintain past investments. The design of projects has too often ignored the fragility of African institutions and the scarcity of skilled manpower. And, perhaps most important of all, African countries have not been held to the standard of performance common elsewhere in the world, including other low-income countries (Jaycox, 1985: 11)

By committing about US$ 4 billion a year for agricultural loans, the World Bank is the undisputed leader in setting the policy direction for agricultural lending in the Third World. Over the past decade, the Bank committed about US$ 33 billion –one-third of its lending portfolio – for agriculture. When cofinancing with other donors is taken into account, the total outlay for agriculture is US$ 90 billion over the past 10 years (Jaycox, 1988: 15). Moreover, the Bank recently announced that it plans to invest $6 billion to $7 billion in agriculture in Africa over the coming five years (World Bank, 1988e). The Bank's high-profile role in African agriculture underscores the political significance o a new Bank initiative in a complex area such as agricultural research.

But the Bank is a relative newcomer to agricultural research. It made its first agricultural research loan to Spain in 1970. It threw its weight behind agricultural research in Africa in 1979 with a loan to the Sudan. It is now supporting or planning t support research projects in 16 countries in sub-Saharan Africa (World Bank, 1988e: 22). The Bank committed US$ 1.3 billion to agricultural research worldwide during th six-year period, 1981-1986, including US$ 314 million for Africa (Pritchard, 1988).[25]

In March 1988, the World Bank unveiled a strategic framework to guide its support of agricultural research in Africa – *Strengthening Agricultural Research in Sub-Saharan Africa: A Proposed Strategy* (World Bank, 1988c). The report reflects a "consensus" that emerged after a three-year study and a period of consultations and meetings, including a high-level meeting of African policymakers, researchers, and donor representatives in Feldafing in 1987 to review the draft report (Pickering, 1988). The central question that can be raised about the Bank's proposed strategy for Africa is the following:

- Will the implementation of the strategy lead to productive, cost-effective, and sustainable NARS or will it possibly increase the dependency of some NARS on the international donor community, the CGIAR, and the French research establishment for decades to come?

This overarching question will be explored by examining five issues related to the Bank's strategy for Africa:

1. Africa's early stage of institutional development

The Bank's strategy is based on the implicit assumption that all African countries are at a fairly similar stage of political and institutional maturity and that the limiting factor of NARS is financing for buildings, equipment, vehicles, and operating costs. Over the past decade, the Bank has a demonstrated record of designing fairly large ($15 to $50 million) projects with other donors as cofinancers, and disbursing these funds through short-term (five- to seven-year) projects. By contrast, USAID's strategy to strengthen NARS in Africa is based on the implicit assumption that African countries are at different stages of institutional maturity and that strategies of foreign assistance must be tailored to a nation's stage of development and absorptive capacity (USAID, 1985). For example, USAID's strategy breaks new ground by dividing the 45 NARS in Africa into eight to 10 TP/NARS and the balance into technology-adapting (borrowing) NARS (TA/NARS).

2. Resource-transfer model

The Bank carried out extensive background studies over a three-year period to aid in the preparation of its new strategy. But these studies did not include the collection of original data on the economics of investment in research in any commodity or in any NARS in Africa. Nevertheless, the Bank's strategy assumes that African states should spend 1% to 2% of agricultural GDP on agricultural research – the same level that many industrial countries are spending. The Bank's strategy presents a consensus view (of donors and African planners and research managers) that large transfers of financial resources are needed to strengthen NARS in Africa. Since the Bank's strategy is partially designed to mobilize donor support to cofinance research projects, it will be warmly endorsed by political leaders and the directors of NARS in Africa. But the challenge is to move beyond the resource-transfer model of building buildings and purchasing equipment and vehicles, and to develop a human-capability/institution-building model that is geared to the realities of Africa in the 1990s. The three hallmarks of the human-capability model are 1) the slow, step-by-step process of improving the quality of the scientific, managerial, and financial capacity of a NARS, 2) upgrading the quality and relevance of research programs, and 3) developing support from clientele groups to finance and sustain the research system from domestic sources.

3. *Tapping Africa's research experience*

The Bank's strategy does not explicitly draw on Africa's research experience over the past six to seven decades in developing a strategy for the coming 30 years. For example, why were small teams of scientists (two to six) so productive during the colonial period? What does this experience suggest for the current proposals to finance the expansion of NARS in Tanzania, Niger (Niger and ISNAR, 1988), Mali (Mali and ISNAR, 1988), and other countries? The Bank's proposed strategy also fails to draw insights from some of the contemporary African success stories in agricultural research. For example, what was the role of public and private research in helping to triple smallholder maize production in Zimbabwe from independence in 1980 to 1987 (Rohrbach, 1988)? What can Africa learn from Malaysia's pioneering research in biotechnology (National Council for Scientific Research, 1985)? Zimbabwe is planning to set up a private biotechnology research institute. Should African countries set up private or public biotechnology institutes or rely on industrial countries for biotechnology?

4. *The puzzle of francophone West Africa*

The Bank's research strategy for Africa does not analyze why francophone countries are so heavily dependent upon expatriates relative to anglophone countries. For example, after three decades of independence, why are 73% of the agricultural researchers and teachers in Cote d'Ivoire still expatriates (Table 2)? Is this desirable? The Bank's proposal studiously avoids this issue. How do NARS maintain research quality (e.g., cotton research) in francophone West Africa while progressively developing a cadre of national scientists and reducing the dependency on expatriates? This is a puzzle that requires attention at the political and technical levels.

5. *Sustainability – The neglected issue*

Over the next five years, the Bank plans to help mobilize $US 3 billion of resources for agricultural research in Africa ($1.5 billion into NARS and 1.5 billion into the CGIAR system) (World Bank, 1988e:). There is a high probability that transferring an average of $300 million a year into the NARS over the next five years will overload the NARS with buildings, equipment, and increased recurrent costs under the banner of conforming to the 1% to 2% investment target. The end result may make African NARS more dependent on the CGIAR and French research institutes and international donors, and *postpone the day of reckoning* – i.e., developing local political support to finance the core costs of NARS from domestic sources as the key to sustainability of NARS. In short, the Bank's strategy has dodged the critical question of how to increase the financial sustainability of NARS.

I am convinced that the five issues flagged about the Bank's approach to strengthening agricultural research in Africa will slowly emerge as the critical issues under public debate in the 1990s. In fact, some of the reservations that I have raised about the Bank's resource-transfer model were recently echoed by a World Bank official at the Bank's 1988 Agriculture Symposium:

> It is reasonable, as has been seen in many cases, in particular in Africa, to promote – not to say to force – the creation of bureaucratic, civil service systems in places where there is no commitment, political or othertwise, and where there are serious doubts as to the ability of governments to finance such systems from budgetary resources" (Lafourcade, 1988: 65).

In summary, the World Bank is providing financial but not intellectual leadership in strengthening the institutional base of African agriculture. Despite the unlimited resources at its disposal, the World Bank does not have a cadre of core staff and consultants who have the time to study and reflect, and the freedom to design long-term projects that slowly and progressively strengthen the human capability of national agricultural research systems over a period of decades.[26]

Implications for African States, Donors, the CGIAR, and ISNAR

The thesis of this paper is that many African countries are generations, and a few are several centuries, behind Asian and Latin American countries in terms of their stage of human capability and institutional and political maturity. What flows from Africa's agricultural research history over the past 60 years is the simple but powerful proposition that current institution-building strategies and lending approaches that are effective in Asia and Latin America will have to be sharply modified to fit the earlier stage of development of many countries in Africa. In addition, because of the differential stages of development between African countries, institution-building approaches in middle-income countries in Africa, such as Zimbabwe and Cameroon, are likely to fail in Guinea, Chad, Burundi, Somalia, Uganda, and Ethiopia.

Institution building strategies should be tailored to the stage of a nation's institutional, scientific, and political maturity. The World Bank's proposed Africa-wide strategy for strengthening NARS is almost certain to be ineffective. Instead, a subregional strategy should be prepared to strengthen the three core national agricultural services – research, training, and extension – for each of the five major agroecologies: Sahel, coastal West Africa, Central Africa, Eastern Africa and the Horn, and Southern Africa. Each strategy should include the basic concept of TP/NARS and TA/NARS, and research networks to link researchers in NARS with regional and international institutes.

Now is the time to start fresh and examine the causes of differential stages of institutional maturity in Africa and the incremental nature of building scientific capability. The starting point should be a thorough review of what has been learned about Africa's agricultural research history over the past 60 years (Carr, 1982; Anderson et al., 1988). The second step is to improve our understanding of the payoff to investment in agricultural research by undertaking a set of comparative studies of the economic rate of return on past investments in research (Echeverria, 1988). ISNAR is the logical institution to undertake studies of the payoff to investment in food, export crops, and livestock because it has generated a global data base for agricultural research (Pardey and Roseboom *in press*; Pardey et al., 1988). Although studies of past investments in research offer limited guidance on how much to invest in research in the future, they will help Africa gain a better understanding of its agrarian heritage. The results of these rate-of-return studies will also serve as a bridge to ex ante studies of potential future returns on investment in public and private research in Africa.

Feasibility teams preparing donor projects to assist NARS should discontinue using rate-of-return coefficients from other continents to justify investments in NARS in Africa. Moreover, the use of the 1% to 2% of agriculture GDP as the guideline for investment in NARS in Africa (World Bank, 1981a) should be discontinued because there is no empirical foundation from Africa to support the use of the norm. In practice, the 1% to 2% guideline allows donors to sidestep thorny issues such as recurrent costs and financial sustainability.

Donors should come to grips with the immensity of Africa and the diversity of its colonial heritage and uneven prospects for development. Investment in research, training, and extension should be conceptualized as part of an interactive investment package on a subregional basis, such as the Sahel or Southern Africa, in a 20- to 30-year time frame. The present project-by-project and country-by-country approach to strengthening national agricultural services is a politically safe but technically flawed approach to institution building. The subregional approach to research planning has the potential of capturing research spillovers. But to implement such an approach, African states and donors must deal with some complex political issues limiting the development of sustainable institutions. For example, because of the different nature of the international political interests in francophone West Africa and Southern Africa, the approach to strengthening NARS in these two subregions will be radically different.

Subregional research investments should be conceptualized as part of an interactive package where regional spillovers are a fact of life. The TP/NARS concept in the USAID (1985) strategy is one that should be factored into the preparation of subregional plans to strengthen NARS. WARDA (1988) and IITA (1988) recently prepared brief sketches on how they propose to strengthen NARS in West Africa. The sketches reflect the lack of a clear mandate to deal with the complex political, technical, and financial issues in strengthening indigenous scientific capacity in West Africa. But the WARDA and IITA sketches are a beginning. They need to be placed side by side with the plans of NARS, SPAAR, and CGIAR, as well as with plans by bilateral and multilateral donors. There is an urgent need to set up a SACCAR type of organization for the Sahel with a full-time African director to guide donor investments in agricultural research and promote research cooperation among scientists in the region. A similar type of organization is needed for coastal West African countries.

ISNAR has a special responsibility and opportunity to work with NARS, donors, the CGIAR, and French research networks to develop subregional plans to strengthen NARS. There is need for the CGIAR to supplement the counting of hectares as a measure of the production impact of a CGIAR center with new measures of the performance of research institutions over time. For example, how does one measure the performance of the SADCC/ICRISAT sorghum and millet center based in Zimbabwe in terms of its progress in helping strengthen NARS in Southern Africa?

The mission of the CGIAR system and the approach that it uses in dealing with NARS in Africa should be reexamined. When George Harrar, F.F. Hill, and others were laying out the CGIAR system in the early 1960s, they had a limited time horizon of 15 to 20 years in mind for the system. F.F. Hill, an agricultural economist and then vice-president of the Ford Foundation reported that whereas every state in the US, for example, had a college of agriculture and a system of experiment stations, a "half-dozen leading colleges of agriculture produced the bulk of the new technology" (Hill, 1964). Hill observed that this concept of technology-producing states could be used to set up "regional research organizations" – International Agricultural Research Centers (IARCs) – in less-developed regions. Hill contended that these new IARCs in the Third World should have continuity of funding from public and private sources for a "sufficiently long period of time to enable them to carry out their assigned missions. This will usually require fifteen to twenty years, sometimes longer" (Hill, 1964: 152).

In the early 1960s there was a general perception that the Ford and Rockefeller Foundations could withdraw and transfer the management and support of the early IARCs (Cimmyt and IRRI) to the host countries over a period of several decades (Ruttan, 1987). But one CGIAR center has celebrated its 25th anniversary, another its 20th, and both are planning programs for the year 2000. In short, the CGIAR system is firmly entrenched, and a few scholars such as Prof. Ruttan have argued that the CGIAR system should be given permanent status in the global research system.

Nevertheless, after 20 years of CGIAR activities in Africa, the CGIAR system does not have a feasible plan of action to strengthen Africa's NARS. Before the CG system brings more centers under its control, four hard questions about the CGIAR's role in Africa should be addressed:

- What constitutes a successful international effort in agricultural research in a subregion of Africa such as the Sahel? Should donor assistance to the CGIAR system be evaluated on the basis of the volume of new technology produced, or on the dual objectives of producing technology and strengthening NARS?

- Is the CGIAR prepared to modify its technology-generating focus in Africa and develop a dual strategy of generating new technology and strengthening NARS?

- Is the CGIAR prepared to rebudget human and financial resources to help improve the capacity and increase the sustainability of NARS?

- Are the French research institutes prepared to develop and implement a strategy (in cooperation with the CGIAR) to strengthen NARS in francophone West Africa?

To address these and other questions, ISNAR should map out a 10-year research program on "Sustainable NARS in Africa."

Notes

1. World Commission on Environment and Development (1987).

2. No countries in sub-Saharan Africa were included in the 23 studied.

3. Historical studies of agricultural research policy include a study of 60 years of agricultural research history in Uganda (Carr, 1982) and Prof. Idachaba's study of agricultural research policy in Nigeria (Idachaba, 1987).

4. About US$ 90 million was spent on the 1200 long-term advisors, and about $10 million, on overseas training in 1985.

5. For an extended discussion of the five prime movers, see Eicher (1988a, 1988b). The prime movers are favorable economic environment, human capability, new technology, rural capital formation, and rural institutions.

6. The 1900-1929 period in anglophone countries is admirably chronicled by McKelvey (1965), Jeffries (1964), and Masefield (1972). I am not aware of a definitive history of agricultural research in francophone Africa.

8. In 1947, the French established the Institut de recherche pour les huiles et oleangineaux (IRHO) to carry out research on oil palm. Cooperation between INEAC and IRHO scientists played a critical role in developing the modern oil palm industry in cote d'Ivoire.

9. Processing of the rice research results was greatly aided by the arrival of a large IBM mainframe computer at the Yangambi station in 1956 (Tollens, 1988).

10. At independence in 1960, there were 420 European (mostly Belgian) scientists and technicians, of which more than half were university graduates. In addition, there was a Congolese labor force of 12,000 to support 17 research stations, 14 experimental plantations, and a veterinary laboratory (Drachoussoff, 1965: 188). But Guy Rocheteau of ISNAR reports that in 1988, there are only 43 national scientists in Zaire's NARS (see Table 2), supplemented by 56 national and 11 expatriate scientists in a separate research and extension project in the Ministry of Agriculture.

11. See Eicher (1984) and Rohrbach (1988) for more information on Zimbabwe's maize industry.

12. A.G. Rattray served as director of maize research from 1938 to 1968, at which time he retired from government service. Zimbabwe's maize research program has been directed by only four scientists over the past six decades (1932-1988), a record of continuity that is unmatched almost anywhere in the world.

13. Institut de recherche du coton et des textiles exotiques (IRTC).

14. Compagnie Francaise pour le developpement de fibres textiles (CFDT).

15. The last expatriate scientist left CRIG in 1962. For more details see Martinson et al. (1987).

16. The number of Ghanaian scientific staff increased to 11 (of 17 total) in 1970 and to 25 by 1985.

17. See Malaysia (1986) and PORIM (1985) for a discussion of the aggressive steps taken by Malaysia to become the dominant world oil palm producer and a leading generator of biotechnology (National Council for Scientific Research, 1985).

18. Institutional models include integrated rural development (IRD), agricultural (area) development, T & V extension, farming systems, discrete agricultural research projects, and research components in area development projects. Technical-assistance models include short-term consultants, long-term resident expatriate advisors, counterparts, and overseas training.

19. See Cernea (1985 and 1987), Dyson-Hudson (1985), Zurek (1985), and Birgegard (1987).

20. For an upbeat assessment by a World Bank official, see "A Successful Managerial Approach: The Training and Visit System of Agricultural Extension" (Israel, 1987: Chap. 10).

21. Invariably, loan, credit, and grant agreements are vague on the source of the extra government budget resources expected to take up the slack after the loan or grant is disbursed. Because extra revenue is not forthcoming in most cases, the project activities are terminated or dramatically scaled back when foreign assistance is over. In some cases, the project is "repackaged" and another donor takes over.

22. For a discussion of the recurrent cost problem, see Heller (1979), CILLS/Club du Sahel (1980), USAID (1982), Howell (1986), Morss (1984), and Gray and Martens (1983).

23. Idris (1969) summarizes 50 years of cotton research in Sudan from 1918 to 1968, and Martinson et al. (1987) review 48 years of cocoa research in Ghana.

24. Prof. Eric Tollens is carrying out a study of the returns to Belgian investment in agricultural research in Zaire (formerly the Belgian Congo) from 1933 to 1959.

25. These figures include allocations for free-standing agricultural research projects, and agricultural and regional development projects with research components.

26. For valuable perspectives on this complex process see Odhiambo (1967, 1987) and Rocheteau et al. (1988).

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Rationalizing Donor Support for NARS

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In the last few decades, the world has witnessed a substantial increase in agricultural production The extraordinary achievements in agricultural development and research have made it possible to produce enough food to feed the entire population of the world.

The enormous production potential of the European Community, the United States, and Canada, which so far has not been fully exploited, is evidenced by huge production surpluses. Over the last 100 years, agricultural yields in most industrialized nations with large agricultural sectors have grown five- to six-fold.

Today, we are able to produce more than enough to feed the world's population. In the foreseeable future, the technicalities of food production will not constrain world population growth. Many studies have concluded that the earth's potential productive capacity is sufficient to feed more than three times its current population. The pessimism of Malthus would appear to be without foundation.

To the casual observer, and I can think of a number of politicians who fit that description, it appears that in view of the widespread production surplus in most industrial countries and even in some developing countries, agricultural research has done its duty, or at least that it need not have priority in the future. It is merely a matter of distributing and transporting food surpluses to needy countries.

That this is not the case quickly becomes clear if one looks at the problem more closely. Today, no one knows if agriculture will have developed sufficiently to ensure a food supply for the world's population by the turn of the century. What we all want, and to that end we have joined forces, is the development of the Third World. Development means, however, that each individual and every nation can freely unfold the creative talents they possess. The foundation of development must be the ability of Third World countries to feed themselves.

Economic and social discrepancies between North and South, between industrial and developing countries, are nowhere so apparent or so disturbing as in the case of food supplies. In the South one person in every four has to go hungry, while the storehouses of the North are not large enough to hold all the surplus grain, meat, and dairy products. In the South undernourishment is one of the commonest causes of mortality, but overnourishment in the North poses a growing threat to health. Removing this glaring disparity between hunger in the South and surplus in the North, or at least reducing it to a tolerable level, is a challenge which we all face.

Let us look at the food situation from a regional point of view. The agricultural commodities market of the European Community is characterized by surplus production mainly of basic foodstuffs. The citizens of the European Community enjoy a nutritional level that the countries in the Third World do not dare to dream of. Similar conditions are found in other industrial countries.

Judging by FAO's reports and statistics, a slow but nonetheless constant improvement in the food situation can be detected in Latin America. Between 1968 and 1983 food production rose by approximately 3% each year. There are, however, countries or areas within the region that are still lagging behind, for example Haiti, northeast Brazil, and the Andes Mountains.

About 1.4 billion people, almost one-third of the world's inhabitants, currently live in Asia. There are great differences in the way the general food situation has developed in each individual country. In the 1960s, India was still the country where hunger and starvation were most widespread. Today, India actually exports agricultural products from time to time, thanks to the success of the Green Revolution. In 1984, for example, 40% more rice and almost 80% more wheat were harvested than in 1974.

China, which experienced atrocious famines between 1920 and 1923, was able to raise its food production by an annual 5.5% between 1980 and 1984, by pursuing a rigid population policy and by targeting financial resources to the agricultural sector. This figure places China, which has to feed more than 1 billion people, well ahead of other developing countries. In general, finding enough to eat is no longer a problem in China.

For all of us, Africa is the problem continent and a tremendous challenge. Of all the regions in the world, this continent has the lowest level of farming and the least-developed income sources to purchase food and the means of production. It is expected that from now until the year 2000 Africa's population will grow at 3-4% annually, the highest rate in the world. The Malthusian nightmare threatens to become reality, for in Africa population growth has outstripped the food supply. You will all remember the terrible famine of 1984-1985, and still today news reaches us almost daily of people threatened by starvation in Ethiopia, the Sudan, Chad, and the Sahel.

The 1984 FAO publication, *Land, Food and People*, reported:

> On present trends, much of Africa – especially the Sahel, the dry belt in the south of the continent, the Horn of Africa, and East Africa – appears to be heading towards human and ecological tragedy, unless far greater priority is given to agricultural development, conservation, and programs to reduce population fertility than has hitherto been the case.

This statement is confirmed by every analysis of the food situation in Africa.

The encouraging reports of good harvests and full storehouses in some African countries cannot obscure the fact that long-term food self-sufficiency in Africa is still far from certain. There is no reason as yet to sound the all-clear.

The dire prophecy of Thomas Robert Malthus, made 200 years ago in his now famous *Essay on the Principle of Population* in which he expounded a theory on the interrelation between the growth of a population and its means of subsistence, has not so far come true. On the contrary, in global terms the food supply has grown at a faster rate than the population, but in many regions this has been at the expense of the environment. In some areas, excessive fertilizer applications and irresponsible use of other chemicals have contaminated groundwater and degraded the soil. Natural resources have been exhausted and various species of animals and plants decimated by ruthless agricultural production and monoculture.

To feed 5 billion people has today become too much of a burden in many regions. To make matters worse, the population is still growing. By the year 2000, there will be more than 6 billion people on this earth. Nothing has such a devastating effect on nature as overpopulation. The shortage of food leads to overcultivation of marginal soils or even to farming totally unsuitable land. There is a great danger that the natural resources of soil, water, and forests will be damaged irreversibly by overexploitation, and that deforestation, overgrazing, soil erosion, and desertification will increase at an ever faster rate.

The Sahel region is to a large extent an example of human fallibility in which the donors have shared. In the 1970s thousands of wells were drilled in this region to supply men and animals with water. As a consequence, the water table sank rapidly and large areas were transformed into steppe. The greater availability of water induced the population to keep more cattle, as a result of which pastures were overgrazed and soils soon degraded.

Twenty years ago when agriculture was at a fairly basic level and crops were in an almost virgin state of development, it was comparatively easy to find ways of increasing agricultural production. Today, we are up against the ecological limits of what we can do and what we can justify to future generations. The sort of damage that can be caused to the environment by intensive farming has been partly demonstrated in the industrial states. We cannot afford to go for food security at any price.

Nonetheless, we cannot close our eyes to the tasks in front of us. Securing the food supply through the prudent use of the world's natural resources is a challenge we must face. Undoubtedly, the Green Revolution has brought outstanding results. It has significantly raised agricultural efficiency in Asia and Latin America: for example rice yields increased more than fourfold, and the number of harvests per year rose from two to three. Supporters claim that it is the most significant technical achievement of agriculture in this century, and the biggest success in international development work since the Second World War. Critics reply that the Green Revolution has been a failure for social, ecological, and biological reasons.

It is certainly undisputed that the Green Revolution as a plant production instrument under development cooperation was conceived by its "creators", not so much as a social-political measure, but rather as a quick countermeasure to hunger in the world. The Green Revolution of the late 1960s is not identical with that of the late 1980s, which in turn will be different from that of the year 2000. To judge the past with the benefit of today's knowledge is to risk condemning the past in its entirety and to ignore the learning process. We have not only learned from mistakes and undesirable social and ecological side effects, but there has also been a change in the overall philosophy behind our development cooperation. Today, the small farmer and the cultivation of indigenous food crops are the focus of rural-development strategies. "Including the target groups in the rural areas," "help towards self-help," and "structural adjustment" are nowadays the preferred strategies. Ecology and the preservation of natural resources are to an increasing extent an essential concern of any development policy.

International agricultural research, represented by 13 research centers within the Consultative Group on International Agricultural Research (CGIAR) and some 14 other centers outside this group, should not have fixed objectives. Rather, they must leave room for continuous feedback, adjustment, and change. If viewed in this way, agricultural development is not possible without agricultural research. Within limits, it should be possible to be flexible and adaptable as priorities in international agricultural research change. We should therefore give thought to restructuring and adapting the mandates and tasks of the CGIAR institutes. This certainly does not mean a radical substitution of new for old; it is rather a question of wisely adapting the old ways to new requirements. In the future, there should perhaps be more burden sharing in agricultural research, for example by working out which research work and mandates can be left to our partner countries. People tend to rise to their tasks, and from my point of view it would be quite conceivable to have the so-called threshold countries take over part of the work done at the international research centers. In other words, we need more free scope to tackle urgent new tasks in connection with food security and the preservation of natural resources.

As I mentioned, we have more than 27 international research institutes concerned with agriculture and associated specialized fields. Despite this fact, there is not a single institute dealing intensively with forestry research. This is a sad state of affairs given the enormous problems which must be solved involving forestry in developing countries.

Another important problem is the worldwide production losses caused by insect pests and diseases: they are estimated at 20-30%, and post-harvest losses at 10-20%. Reducing these losses by half would be a considerable contribution towards food security. Recently, locusts have again become a factor in causing enormous production losses. Eradicating this plague is a challenging task for research.

The field of biotechnology opens up new perspectives to improve the cultivation of food crops in terms of:

• high and stable yields;

• a reduction in the need for water;

• a reduction in the need for fertilizers and pesticides.

Securing food production in the long term with little ecological and economic risk and with only few inputs is a necessity, especially for Africa with its ecologically fragile soil. In Africa as elsewhere, land available for agriculture will become scarce in the long term because of population growth. Consequently, what we must do now is offer farmers production methods appropriate to the locality as an alternative to the ecologically dubious method of shifting cultivation. I have just mentioned the outstanding results achieved as a result of the Green Revolution. It had an impact in Asia and parts of Latin America, where circumstances were favorable to production of new high-yielding varieties of maize, rice, and wheat. The Green Revolution has passed Africa by, virtually without trace. On the one hand the preconditions were lacking to use new varieties since wet rice, wheat, and the new varieties of maize had seldom been grown in Africa in the past. A Green Revolution for Africa must improve and secure native African crops if it is to be successful.

A chain is only as strong as its weakest link. The efforts of international agricultural research will be in vain if it does not have the support of effective national research and extension services. Without national agricultural research, research at the international level is isolated and its results cannot be put into practice. The task in hand therefore – and here I would like to appeal to the governments of the Third World countries and to the donors – is to establish and jointly build up national research services which are capable of meeting the challenges of the future. This is the purpose, among others, of this conference. When ISNAR was founded in 1980, it was inspired partly by a desire to strengthen national research, to identify research problems, and to formulate research strategies and policies.

SPAAR

At the beginning of my statement, I noted that development and food security in Africa are tasks in which we are all called upon to play a part. This applies equally to national research in Africa within the framework of international agricultural research. In response to the proposal from the World Bank, the Special Programme for African Agricultural Research (SPAAR) was set up in 1985 to coordinate existing and future donor activities which establish and improve national research in Africa. The SPAAR secretariat is financed by the World Bank, and also has its headquarters there. The chairman of SPAAR is Dr. David Hopper, who is also chairman of the CGIAR.

Coordination and information are two of SPAAR's primary tasks. What donor knows the programs and projects of any other donor? Where are there overlapping activities, or worse, those which directly conflict with the project of another donor? The first step, therefore, would be to gather information and make it available. The Third World countries themselves should be in a position to coordinate activities and collect information on research projects. Nearly all the donors involved in international agricultural research are members of SPAAR. All SPAAR members are agreed that, in the final analysis, the only strategies to support national research which have any chance of success are those which are developed jointly with African partners. It is for this reason that African researchers are regularly invited to attend SPAAR meetings and working groups so that they can contribute their own specialist knowledge.

The point is that SPAAR has no funds of its own. At SPAAR meetings and working groups, certain specialized fields and programs are discussed which would lend themselves to joint action: individual donors would implement individual actions or make funds available for such purpose. I would like to elaborate on this, taking as an example the various current activities of SPAAR.

The establishment of a SPAAR information system

Information on past or current research activities in a country, or activities which may be conducted in the future, is the basis of any long-term research strategy, and guards against duplication. SPAAR has called on its members to register research activities carried on in Africa on a bilateral basis. In the first instance, they are interested in data and information on agroecological zones, research targets, research areas and disciplines and, if appropriate, the financial contribution to the project. In each donor country, focal points have been designated which are responsible for gathering research information in their respective countries. This information is passed on to the SPAAR secretariat where it is stored in a central computer. All donors, as well as institutions and individuals in Africa, have access to the computer. When this information system was set up, care was taken to ensure that it was compatible with existing information systems such as the CARIS and AGRIS systems of FAO.

There are also plans to store information on nationally funded research projects in Africa to complete the picture. I believe this is an essential step. For many years a great deal of research work has been going on in African countries, whether at universities or agricultural research institutes, under national programs. Much of the work has been published, but not all, and the unpublished work needs to be evaluated. Setting up an effective information system in African countries is a primary task in strengthening national research.

Guidlines for national agricultural research strategies

To assist African governments in strengthening their national agricultural research capacities, SPAAR set up a working group to prepare guidelines for national agricultural research strategies. The first draft, prepared by ISNAR for the working group, broadened the objectives of the paper to deal with research systems generally rather than limiting it to strategies. Accordingly, the title was amended to *Guidelines for Strengthening National Agricultural Research Systems in Sub-Saharan Africa*. The draft was presented at the SPAAR meeting in Washington, D.C., in November 1986. A revised draft was then given to African agricultural research directors attending the Nairobi and Cotonou regional meetings organized by the World Bank in December 1986. The document was approved at the May 1987 SPAAR meeting in Paris. The English and French versions have been widely distributed to African countries and the donor community.

Assessment of promising technologies

Another SPAAR project is the assessment of information on promising technologies. Considerable research work on various aspects of African agriculture has already been done, but the results have largely been underutilized for a variety of reasons.

French and British scientists have undertaken the assessment of promising technologies in Senegal and Sudan, respectively. Both teams were looking at clearly defined agroecological zones. Initial efforts have uncovered a surprising wealth of information and research results. It is believed that some of the technologies may be applicable, but they were apparently never used at the farm level, either because they were not tested or the results were not published. Both teams indicated that the results of their studies will mainly be of methodological value. Their final reports were presented at the Fifth Plenary Session in Washington, D.C., in October 1987.

Meanwhile a similar study has been commissioned jointly by SPAAR and the Tanzanian government. This will provide the basis for a master plan of national research and research priorities in Tanzania.

Regional collaborative networks

Some countries in Africa are too small to work on all the commodities relevant to them. This is why networking is becoming extremely important.

Research networking is not new. The international germ-plasm nurseries set up in different ecological zones by IRRI for rice and CIMMYT for wheat are well known. What is new is the proliferation in the last few years of research networks in sub-Saharan Africa and the fact that research networking has expanded. In addition to testing advanced breeding material in different zones, networks now deal with the transferability of agrotechnology within soil families, the use of crop by-products for livestock feed, pasture improvement, livestock diseases, insect pest control, agricultural machinery, soil and water management, and farming systems.

Despite the very rapid increase in the number of research networks in Africa, collaborative research is not as well developed as it is in Asia or South America. The main reason for this is that there are fewer well-trained research managers and scientists in Africa to manage the networks.

The SPAAR Working Group on Networking was established to collect information on networks in Africa, understand their needs, and identify ways of making them more effective. The working group produced a list of known networks, categorized them into three main types, and identified 14 networks that fulfill the SPAAR criteria for collaborative research networks. Networks meriting financial support are being identified, and mechanisms to finance these networks are also being studied. Coordinators and steering committees of selected networks are assisting in the evaluation.

Provision of small grants for African researchers

One of the major problems for young scientists today is funds for research. Those who have been trained for higher academic degrees abroad find it difficult to finance their research on their return, and many of them decide to emigrate. This brain drain can be avoided if the young scientists are supported internationally at the beginning of their research career with funds for equipment, materials, and scientific guidance. It is remarkable when one looks around how many small things are missing. There are few scientific books, journals, and facilities for up-to-date information. Sometimes there is no transport to reach farmers' fields, and no travel money to attend meetings with colleagues from other African countries. Often the equipment a researcher badly needs for his work is missing, broken, or cannot be repaired because spare parts are not available. Here one could help with a relatively small amount of money.

SPAAR has asked the members to support those scientists in Africa to enable them to carry out research work for their country. About US$ 2 million was made available for this year. The International Foundation for Science (IFS) has been chosen to handle this money for SPAAR, which is earmarked for individual scientists in Africa. IFS, founded in 1972, is a nongovernmental organization with a membership of 77 scientific academies and research councils in 67 countries, of which two-thirds are in developing countries and one-third in industrial countries. IFS is governed by an international board of trustees, with its secretariat in Stockholm. The Foundation provides support to outstanding young scientists and technologists from developing countries.

Reinforcing forestry research

This is another field which requires urgent action. I have already pointed out that there is no institute at the international level dealing comprehensively with forestry research. In a working group with interested donors and African experts, SPAAR is trying to identify research priorities in this field and implement a solution.

Assessment of higher education and training needs

The need to improve the quality of higher education and training for African agricultural scientists has been underscored by African decision makers. SPAAR donors at the Fourth Plenary Meeting in Paris agreed that a new working group on education and training should be established to examine the issue of higher education and training in Africa.

Donor coordination group on Tanzania

We are all aware that national research is not pulling its weight as a link and mediator between international agricultural research and extension services and small farmers. This is particularly true in Africa. The reasons are well known and I do not need to repeat them here. We also realize that without effective national research, the results of international research cannot be applied, and long-term food security in Africa is threatened. What is more, national research in Africa is in danger of slipping so far behind the enormous progress being made by research in the industrial nations that it may no longer be able to catch up. The situation is clear and we should not waste any more time on theoretical discussions or lengthy conferences.

In the autumn of 1987, SPAAR proposed to its members that national research should be established and strengthened in an African country on the basis of concerted action. The results and recommendations which have emerged from the various working groups of SPAAR could be fed in gradually.

In response, a proposal was drawn up jointly by the World Bank and Tanzanian government in which the World Bank suggested that the rehabilitation and expansion of national agricultural research in Tanzania be supported by interested donors and implemented. This proposal – the Tanzanian National Agricultural and Livestock Research Project – has been planned in Tanzania for about eight years. National research in Tanzania is not starting from scratch, as we all know; it has a solid foundation. There are two universities and a large number of agricultural research stati ons which will serve as a foundation on which to build.

Yet, for many reasons, research in Tanzania has still not succeeded in coming up with solutions to the myriad problems confronting agriculture. Researchers have not managed to develop adapted production methods for the various ecological zones in Tanzania. So far 20 different agroecological zones have been identified in Tanzania for which there are no detailed data. What is more, national research has not so far come up with high-yielding, disease- and drought-resistant cereal cultivars adapted to the local conditions of small farmers. Worse still, plant protection agents and fertilizers are applied without regular checks and without any scientific investigation of their effectiveness and possible detrimental effects on natural resources. We cannot close our eyes to these facts. Yet there are many problems and difficulties facing national research in Tanzania: personnel who are not suitable, experienced, or motivated; and a research budget which, while meeting labor costs, makes no provision for urgently required means of production, laboratory materials, or transport. To further complete the picture, there is very little coordination between research, training, and extension services. The main victim of all this is the farmer, the backbone of food security, and as in many other African countries, the dynamo of economic development.

All this is no secret, and in this respect Tanzania is no different from many other African countries. Consequently donors have every interest in strengthening national research. The donor community would first like to see a well-drafted, logical, realistic plan for the establishment and development of research structures and their priorities. The plan should build on reliable data; it should clearly point to the gaps and difficulties of research; identify the bottlenecks in the infrastructure, basic and advanced training, and research management; and finally, pinpoint the necessary links and cooperation between producers, extension workers, researchers, and politicians.

In the documentation of the project developed by the World Bank and the Tanzanian government, the framework for all this is clearly set out. The project is regarded as the first phase of a long-term program to expand and strengthen agricultural research in Tanzania. Livestock, cotton, roots and tubers, and farming systems are regarded as priorities, and are suitable for immediate support. The remaining areas, as well as the research structure, are subject to the results of a research master plan, which, following Tanzanian government approval of the overall project, should be started as early as possible.

So far six SPAAR members are involved in the implementation of the project: the World Bank, United Kingdom, Italy, IFAD, Netherlands, and Federal Republic of Germany. In addition, the African Development Fund (ADF) has expressed its willingness to participate in the project, probably in the field of livestock research.

A workshop financed by the United Kingdom and the Federal Republic of Germany was held in Arusha in April of this year. The majority of participants were Tanzanian scientists and experts from the various ministries.

The main aims of the workshop were to provide a forum to:

- identify the major issues to be addressed in the master plan;

- elaborate terms of reference for the master plan team.

The workshop was opened by the Minister of Agriculture and Livestock Development, who outlined current government thinking on research policy and strategy in Tanzania. Several overview papers and national program papers covered past research findings, the current program, and major constraints associated with its implementation, as well as priorities for future research. These papers, along with subsequent discussions, formed the basis for determining the major issues to be addressed in the master plan.

In addition to the master plan, the Tanzanian government commissioned a state of knowledge report from a team that has been asked to assemble all relevant research results and data concerning studies and research work in Tanzania going back to the year 1900. The study is being financed jointly by the United Kingdom and the Federal Republic of Germany. This is similar to the study conducted for Sudan and Senegal under the auspices of SPAAR.

The master plan itself is a matter for the Tanzanian government and the Tanzanian authorities concerned with agricultural research. It is being financed by these SPAAR members: United Kingdom, Federal Republic of Germany, Italy, Netherlands, and IFAD. SPAAR will offer its collaboration to the government and make its expertise available wherever desired. We assume that the Tanzanian universities will assist in drawing up the master plan, since we are concerned with national agricultural research, of which the universities are a part.

The original World Bank project, entitled *National Agricultural and Livestock Research Project – Tanzania*, will, I hope, not be only a World Bank project, but a concerted action on the part of a number of donors. This is not easy, not even for the World Bank. Donor coordination is on everyone's lips, but when it comes time, nobody wants to be coordinated. There is also the problem of differing interests, opinions, and funding sources. It takes time to reconcile all these factors. Hasty action is more likely to be harmful than useful, and one Chinese proverb seems very apt: "You can't make the grass grow more quickly by pulling it." We shall only know afterwards whether the SPAAR objective which we all support can be achieved in practice. The Tanzanian example may show that we are able to engage in cooperative partnership. The master plan is the first real test. The results of the master plan will lead to various activities and programs that will require primarily bilateral financing. The United Kingdom is willing to support cotton cultivation and the Netherlands has expressed its desire to step up its involvement in the field of farming systems.

The Federal Republic of Germany is ready to finance a specialist in organization and management for 5 years. We believe that the Tanzanian case will be of great interest to ISNAR too, since the theoretical recommendations for the support of national research will be thoroughly tested. Assuming the agreement of the Tanzanian government, the expert financed by the Federal Republic of Germany should be provided by ISNAR.

When I spoke of partnership just now I was also referring to partnership arrangements between Tanzanian research institutes and corresponding institutes in the donor countries. This would certainly include basic and advanced training and the exchange of scientists. Partnerships based on sincere intent can endure even after the actual project has been completed.

More and more, agricultural research is becoming a global task. No country can afford to isolate itself as far as agricultural research is concerned. To do so is to run the risk of seeing its own capacities destroyed, capacities which it needs to meet the challenge of food security.

SPAAR is an attempt to help the African countries overcome their already visible isolation in agricultural research.

Conclusion

With the dramatic increase in population, particularly in Africa, and ever-dwindling soil resources, it has become more and more important to use more intensive, although ecologically sound, production methods to achieve food security. Thus the challenges facing agricultural research today are not the same as those of 20 years ago. This is something to which international agricultural research must respond.

However, all the efforts of international agricultural research will be in vain if there is no effective agricultural research at the national level, and an efficient extension service to implement the results.

The donor community is therefore ready to take part in establishing and expanding national agricultural research in Third World countries. The Special Programme on African Agricultural Research, launched in 1985 in the framework of international agricultural research, is a first step towards joint support for national research systems in Africa. Many donors are participating in SPAAR's various activities. Six donors are collaborating in a pilot program for the support of national agricultural research in Tanzania. They will work jointly with Tanzanian experts on the rehabilitation and expansion of agricultural research and implement the results.

Rationalizing Donor Support of NARS (A NARS Perspective)

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The Special Problem of Africa

The food crisis and worsening agricultural trends

Over the past two decades, many countries in Africa have recorded dismal performances in the agricultural and economic development sectors in general, and the food subsector in particular. The continent has moved from a position of being self-sufficient and a net exporter of food products to one of experiencing recurrent food crises. Some countries have had famines and massive food imports, and a number are now dependent on food aid. The annual growth rates of per capita food production declined by 0.7% in the 1960s, by 0.5% in the 1970s, and by 1.25% for Africa as a whole between 1980 and 1984. Considerable export earnings, estimated at 25% in 1980 and increasing at the rate of 3% per annum, are spent on food imports, thus constraining the countries' ability to import capital goods and services, as well as to service external debts.

In recent years African governments have expressed the political will to reverse the worsening food and agricultural trends by reviving and revamping their agricultural sectors for sustained growth. Such political will has been expressed in the Lagos Plan of Action (LPA) for the period 1980-2000, adopted by the Assembly of Heads of State and Government of the Organization of African Unity (OAU) in 1980; and Africa's Priority Programme for Economic Recovery (APPER) 1986-1990. The latter was translated into the United Nations Programme of Action for Africa's Economic Recovery and Development (UNPAAERD) in 1986.

In spite of the determination of African governments and the international community to reverse the worsening food and agricultural trends on the continent, there are both internal and external factors that militate against accelerated recovery.

Internal factors

Fast-growing population. The population of sub-Saharan Africa, currently estimated at 460 million, is growing at an annual rate of 3%, compared to 2.7% in the 1970s. The urban population is growing at more than double this rate. The fertility rate is high compared to other continents (for example, Kenya is currently registering an average of 8.3 births per woman, compared to Cuba's 1.8). The majority of the population is either young (below 15 years) or elderly (over 60 years), resulting in a high dependence ratio of 1.0. The dependence ratios in Asia and Latin America range from 0.5-0.8. Approximately 30% of the African population is undernourished. It is estimated that one out of three children die before the age of five, primarily due to hunger and hunger-related diseases.

Limited resource base. The labor force is growing at 1.4% annually, while arable land per agricultural laborer is declining at 0.7% per year. The absence of new agricultural technology has resulted in unemployment, underemployment, and low productivity on the available land.

High costs have reduced the expansion of irrigation. The majority of African countries irrigate less than 5% of their arable land. Forest areas declined 6.5% between 1974 and 1981.

Policy issues. The economic and food production crises prevailing in Africa are partially rooted in colonial policies. Colonial policies were biased in favor of urban development and against food production. They overemphasized exports and neglected the smallholder farm sector. Most African governments have not been able to disengage from these legacies, so the best farmlands, skills, technology, infrastructure, and marketing systems are in the export-commodity sector.

Farmers readily and positively respond to price incentives in generating marketable surpluses. Many countries maintain a distorted policy of both low producer and consumer prices for the politically articulate urban population. High profit margins for food processors and middle men, and export taxes and other levies aggravate producer prices, and are major production disincentives. The scenario is further aggravated by weak or absent support services such as agricultural research, extension services, input supply systems, credit, and poorly developed markets.

Investment in agriculture is low in Africa, averaging approximately 10%. The surpluses generated by the agricultural sector are often invested in the nonagricultural sectors. These low investments in agriculture prompted the OAU (1985) to call upon all African governments to allocate 20-25% of public-sector spending to agriculture.

Many African countries do not have enough adequately trained technicians, technologists, and scientists to enable governments to formulate and implement development programs. Many countries do not have programs to train farmers. In instances where manpower is available, the skills are not efficiently deployed on a sustainable basis. Inadequately trained manpower, or manpower with poor back-up services, impedes agricultural intensification and expansion.

The physical infrastructure necessary to supply inputs, move produce, and effectively deliver services is underdeveloped in Africa. Distances are long and terrain is rugged. Inadequate physical infrastructure severely restricts the transport and trade of food and other agricultural products both within and between countries. Development of an adequate physical infrastructure is an expensive undertaking that is beyond the reach of many African countries.

External factors

Admittedly, the responsibility for restructuring and reviving African agriculture lies squarely with national governments. Major advances could be made by addressing these internal issues. There are, however, many exogenous factors that aggravate the constraints to the already weak systems. These range from natural and man-made disasters to unfavorable international economic environments.

Natural disasters. Natural disasters occur from time to time, and their effects are devastating. The severe Sahelian drought in the 1970s and the 1983-85 drought in Eastern and Southern Africa wiped out large crop areas, decimated large herds of livestock, dried up water sources, and dislocated populations. Occasional floods have similar devastating consequences. Migratory pests that know no boundaries, principally locusts, quelea birds, and army worms, are an ever-present threat. Livestock and plant diseases, along with insect pests, take their toll. The main problem is that African governments do not have the requisite contingency plans and resources to cope with such emergencies.

Foreign debts. African governments are overburdened by excessive external debts, estimated to be US$ 200 billion in 1987. This indebtedness has made countries unable to import capital goods and other services essential for economic revival. It is estimated that the debt-servicing ratio rose from 9% in 1980 to 30% in 1982, with some countries recording 60%.

The external debt situation is exacerbated by the inability of African governments to generate increased export earnings, accumulate sufficient domestic savings, service external debts, and meet other international obligations. The problem is also aggravated by international currency fluctuations, inability of African countries to raise new loans at reasonable interest rates, and the maturing of past loans.

Trade terms have deteriorated considerably to the detriment of most African economies. The prices of non-oil primary products exported by sub-Saharan African countries declined by 35% in real terms between 1980 and 1987. The poor trade terms, coupled with prolonged world economic recession, spiraling inflation, and restricted access to world markets, have exacerbated the poor performance of African agriculture.

Challenge

The major challenge to African scientists, planners, farmers, and the international community is how to enhance Africa's potential to achieve food self-sufficiency and security, as well as make agriculture the engine to power overall economic development. This is possible. An FAO study (1984), showed that collectively African countries have, at the moment, the potential to feed 780 million people (the projected population in 2000):

- 1.5 times at a low level of technology;
- 6 times at an intermediate level of technology;
- 17 times at a high level of technology.

Although regional self-sufficiency could be achieved, major problems would be encountered if every person on the continent were to be adequately fed. There are problems associated with uneven distribution of high-potential land within and among countries which would necessitate massive movement of food, development of elaborate communication networks, removal of trade barriers, harmonization of exchange controls, etc. To achieve these goals would be complex and expensive.

For the short and medium term, action at the national level is more feasible. National governments must use the comparative advantage of their countries' natural resource endowment, and adopt policies favorable to increasing agricultural output. The set of policies that would have an immediate effect on agricultural production include:

- favorable producer price policies;
- generation of improved production technology through research;
- improved extension services and farmer training;

- timely availability of farm inputs,
- agricultural credit;
- development of market systems, outlets, and infrastructure.

Role of Research in Agricultural Development

Expectations from research

Research is vital if agriculture is to prosper. Cases of sustained economic growth and increases in real per capita income in many parts of the world have shown that technological change in agriculture has been a major vehicle of economic growth. It is through agricultural innovation that the production of food and other agricultural products would be accomplished. For most developing countries, a development strategy that does not incorporate technological change in the agricultural sector is unlikely to lead to sustainable economic growth.

A national agricultural research system is expected to be the custodian of the national agricultural knowledge. Governments, industrialists, and other entrepreneurs look upon the research system to provide socioeconomic information required for policy making, planning, and investment decision making. Extension and other support services, as well as producers, require the research system to provide improved plant varieties and livestock species, agronomic techniques that increase production, and crop and livestock protection technologies that deal effectively with biological hazards.

An effective research system should therefore have the capacity for developing a long-term strategy, setting priorities, mobilizing resources, and allocating such resources in accordance with the priorities. It should have a built-in capacity for programming, budgeting, monitoring, and evaluating its research programs. It should continuously strive to improve its physical facilities and human resources. It should manage the information emanating from its research program in a manner suitable for a variety of clientele. It should be capable of tapping world scientific knowledge and materials relevant to its mandate, and adapting them judiciously. Finally, it should forge a close liaison with a variety of related institutions, especially the extension service, higher education, private-sector research, the agricultural industry, international research organizations, and nongovernmental organizations. Unfortunately most African NARS are too weak to perform these functions.

Limitations of research in solving production problems

Research alone does not hold the key to increased agricultural output and should not be expected to do so. Substantial increases in production could result using the currently available technology. The case of maize in Kenya serves as a good illustration.

Maize is the most important food commodity in Kenya. It provides 78% of total cereal consumption, supplies 44% of total energy needs, and 32% of the total protein requirements of the population. The crop occupies more than 20% of the medium- to high-potential agricultural land, contributes more than 19% of national farm-gate value of major crop and livestock enterprises, and utilizes 25% of agricultural employment. It is the most important source of both income and subsistence for the rural poor, and is produced commercially by large- and small-scale farmers.

Over the last 20 years, research in crop improvement and husbandry, and the development of maize hybrids, have substantially increased productivity. Farmers' yields have, however, not had similar gains. The average farmer in Kenya who grows hybrid maize produces about 2 tons per hectare. A good farmer produces 5 tons per hectare, while a very good farmer attains a level of 9 tons per hectare. Research station yields of 11 tons per hectare are common, and it is possible to produce 20 tons of maize per hectare.

The average farmer has a yield 40% of that of a good farmer, 22% of the yield produced by the best farmer, 18% of research station yield, and 10% of the biological limit. Production technology is not a constraint to doubling maize output in Kenya. Rather, a more intensified extension effort, focused on good crop husbandry and supported by appropriate policies, improved input supplies, and marketing channels holds the answer.

Mobilizing Resources for NARS

The current situation in Africa

As with any other enterprise, to be effective, agricultural research requires funds, physical facilities, and human resources. But as noted earlier, the economies of many countries in sub-Saharan Africa have been on the decline since the mid-1970s, with the result that very little of the national expenditure is allocated to agricultural research. The World Bank estimates that seven countries in Africa spend less than US$ 1 million per year on agricultural research and a further 15 countries spend between US$ 1 million and US$ 5 million.

It has been suggested that 2% of a country's agricultural gross domestic product (AgGDP) should be allocated to agricultural research. In sub-Saharan Africa the level of funding ranges from 0.1% to 2% of AgGDP. With the decline in real AgGDPs of many African countries, investment in research has similarly declined.

A number of actions are required to reverse this trend. First, there must be political will; political leaders must appreciate what research can do to identify and implement national development policies. Second, agricultural research scientists themselves must articulate the research strategy and demonstrate potential benefits that can accrue from an effective and adequately funded research system. It is only when technical information is available that rational political decisions on resource allocation can be made on a sustainable basis. Third, the international donor agencies must fill the funding gap that might arise from shortfalls in national allocations.

Action at national level

Agricultural research managers must take certain actions to convince their governments and donors to allocate additional resources to NARS. They must evaluate their national agricultural research system or systems. In its broadest sense, a NARS is all institutions in a country with a capacity to conduct agricultural research (human, physical, and financial resources). The institutions involved include agricultural experiment stations and laboratories, universities and colleges, regional and international research organizations, and private-sector research establishments.

Governments must evolve a system for the organization and management of their NARS so that all institutions comprising NARS have common goals and purposes, and address themselves to priority programs. Very often the management of NARS institutions is scattered over many agencies, be they government ministries and departments, parastatal organizations, or farmer-supported research institutions. Some countries have recently established ministries of research to coordinate research in all sectors of the economy and national activity. Whatever system is adopted by governments, the role of the various institutions must be clearly defined to avoid duplication of effort, and to maximize use of the scarce resources available. The linkages between the various institutions should be clearly defined.

The research system must consider itself as part of the national planning process, aware of the country's multiple national development objectives, its opportunities and constraints. It is within the context of the national objectives and plans that a NARS should evolve its research program and priority projects. Research managers must be realistic about what is desirable at the scientific level and what is feasible on the basis of available resources. Priority should be given to research projects whose results are predictable and whose adoption is likely to have a large production impact.

Longer-term projects require extreme clarity to attract funding. National governments and donors demand that investment projects be evaluated and benefits measured in terms of the economic rate of return to the national economy. Research systems encounter difficulties in justifying investments in some long-term agricultural research projects because of:

- inherent uncertainties about the timing and value of research findings;
- uncertainties on the timing and the extent of adoption of research findings by farmers;
- difficulties in dividing potential benefits between research and other complementary investments (e.g., irrigation, extension, farmer training, improved producer prices, availability of inputs, and improved market opportunities);
- the problem of quantifying other research results (e.g., basic research results) which not only add to the pool of knowledge but also provide guidance and benefits for planning subsequent research efforts;
- the fact that investments in manpower development and infrastructure building are not amenable to analysis based on rates of economic return.

There are, on the other hand, certain aspects of investment that are easily appreciated by planners and which research managers must articulate. These include:

- increasing output from fixed assets;
- reducing inputs required to attain fixed levels of production;
- reducing risks and uncertainties of production;
- improving the product quality;
- making it possible for more land and resources to be devoted to agricultural production;
- ensuring self-sufficiency in food, thus reducing food imports;
- increasing agricultural exports;
- increasing rural incomes and employment opportunities.

Most governments are concerned with the unemployment problem, especially for university graduates. Very often NARS find themselves overburdened by an influx of fresh science graduates who are ill prepared for the research functions assigned to them. The medium- and long-term research plan must include upgrading the skills of those already in the research system.

Research facilities in most NARS (trial fields, laboratories, and equipment) are in poor condition or inoperable. In view of the limited resources available, research managers should give priority to the rehabilitation of existing facilities rather than building new ones.

When developing the budget for research, care should be taken to balance personnel, operational, and capital costs. Very often personnel costs exceed 80%, leaving very little for operational and related recurrent costs.

In conclusion, it is important to realize that it is not possible for national governments and donors to allocate the required resources to NARS unless the research program is well articulated. The research system must promote itself to justify continued support.

Mobilizing Donor Resources

Overview of the pattern of past donor assistance to agriculture

The flow of foreign aid to developing countries increased from 1971-1982. Official development assistance in 1982 was US$ 36 billion, of which Africa received 32% (US$ 13 billion) compared to 42% for the Pacific countries. Most of the assistance was directed to water development, rural development and infrastructure, agricultural inputs, fisheries, agroindustries, and research and training. On the other hand, there were sharp declines in external resources directed to food production, livestock development, river basin development, and manufacture of farm inputs. These latter subsectors are critical to ensure food security in African countries.

Food aid has recently become a significant constituent of the aid flow to Africa. In the 1970s, Africa received only 6% of all food aid to developing countries, but now accounts for 50% of all cereal food aid to the developing countries, thus replacing Asia as the principal recipient. In 1982-83 world shipment of food aid was estimated at 9.25 million tons, indicating the magnitude of the problem.

In spite of the increased level of assistance to African agriculture, there are doubts that the projected investment will remedy the already fragile situation. The Lagos Plan of Action (1980) projected a need for US$ 4.4 billion from 1980-2000. An FAO Study (1979) estimates a net investment of US$ 56-88 billion over the same period. The more recent UNAPPER (1980) calls for a new investment of US$ 57 billion to support African agriculture for the 1986-90 period.

Foreign aid has not had much impact for a number of reasons, including:

- Most external assistance has been directed to food emergencies, balance of payment support, support for economic reforms, and structural adjustment programs. Although these are necessary preconditions for growth, they are not in themselves direct investments in agriculture.

- Very often donors' preconceived notions of the pattern that agricultural development in Africa should take are a condition to granting aid. Many of these ideas are alien to African culture and sensitivities. A growth-oriented approach to development per se may be at variance or even in conflict with social returns and equity which are normally the cardinal themes of development plans and political aspirations in many African countries.

- Multilateral donors have been important sources of funds to developing countries. There has been, however, a sharp decline in multilateral assistance to developing countries since 1980 because of difficulties in replenishing funds to agencies such as IFAD, UNDP, and IDA. The tendency towards bilateral aid means that developing countries have to resort to commercial loans at high interest rates that exacerbate the already unmanageable foreign debt.

- There are long delays in disbursement of committed funds. On the average it takes 4-5 years to disburse 50% of committed funds and 9-10 years to attain a level of 90%. This pattern of disbursement causes long delays in implementing agricultural projects.

- Lack of coordination among donor agencies contributing to the agricultural sector prevents the formulation of comprehensive programs. Individual donors tend to focus almost exclusively on narrow 3- to 5-year projects of their interest.

Major problems are not addressed: nonavailability of counterpart staff, shortage of local resources, and the need to rehabilitate completed projects which are not performing optimally.

Weaknesses in donor support for NARS

It is estimated that sub-Saharan African governments, aided by multilateral and bilateral donors, are spending more than the equivalent of US$ 300 million annually to support agricultural research. The output of research has, however, been disappointing to both NARS and donors for a variety of reasons.

As noted earlier, most NARS have not developed adequate institutional arrangements to manage their national agricultural research programs; the linkage between the various institutions undertaking agricultural research is weak; the technical priorities adopted for research do not address priority problems of the countries; universities and other institutions of higher education are not integrated into the national agricultural research system, are therefore not playing a significant role in agricultural research, and thus affect the quality of research; NARS have no access to ministries responsible for planning and finance; the budget for research is low (0.1-2.0% of AgGDP), unstable, and hard to sustain; personnel costs constitute a very large proportion of the research budget, leaving very little for operations; funds to develop scientific human resources are inadequate such that most scientists are inadequately trained for their tasks; and finally, incentives to attract and retain trained and experienced scientists are inadequate such that there is a high turnover of senior staff.

Donor support to agricultural research has experienced shortfalls similar to those experienced in donor assistance to the agricultural sector in general. The peculiar pitfalls of donor assistance to research can be summarized:

- Donors are unable to cope with weak management structures of research, which is a prerequisite to mobilize and efficiently use external resources. Many of them lack a clear perception of how to participate in the national research program beyond providing technical assistance.

- Donors fund projects of their choice and often propose research projects which are of low priority to governments. As a result, projects in low-priority areas are well funded, while those of higher priority to a NARS are seriously underfunded.

- Many research projects are heavily dependent on technical assistance, and the resources available from donors are only sufficient to support the technical assistance team. This implies that:

- the national government has to reallocate manpower and financial resources from other high-priority projects to meet its obligation to the project;

- only the donor-assisted project is funded while the rest of the research station projects are unfunded;

- there is low morale of local staff engaged in nonfunded projects.

- Project funding is usually made for a short time (two to three years), but in practice becomes very long-lived because of several extensions. Projects fail to train nationals to continue research activities once technical assistance is withdrawn, with the result that the long-term technical assistance team becomes entrenched. Moreover, no funds are available to replace those provided by external sources once assistance is withdrawn, resulting in collapse of the projects.

- The resources for training offered by donors are either oriented to project activities or come from the general training funds of which only a small proportion is devoted to training in agricultural research. This system provides a haphazard pattern of training and is unsuitable to develop human resources in a balanced manner commensurate with national research priorities.

- When donors encounter difficulties in management, funding, and procurement procedures in projects they are supporting, they isolate themselves from the existing government system and evolve their own procedures. Since many donors are involved in funding several projects, many procedures evolve and the problem is magnified many times. The efficiency in project execution that might be realized as a result of speedier procedures is at the expense of rational allocation of all resources in the research system as a whole.

Rationalizing donor support for NARS

There is evidence that many governments in sub-Saharan Africa and donors now appreciate that agricultural research can play a significant role in regional development. The weaknesses at the national and donor agency levels have been identified and, if rectified, the effectiveness and efficiency of both national and donor resources could be improved.

Improved NARS are prerequisite to effective and efficient utilization of both national and donor resources. Consequently, donors and national governments should jointly review the national research systems and strive to improve them.

There should be frequent consultations between national governments and donor agencies so that donors are aware of the national development objectives, strategies, and plans. In countries where many donors are involved in funding components of the national research program, a permanent mechanism should be established for donor coordination. Such a forum would facilitate:

- identification of priority areas requiring research attention;

- development of research programs on a priority basis;

- assessment of the indicative budget requirements, availability of national financial resources, and the resultant funding gap;

- determination of the availability of donor funds;

- assessment of each donor's area of strength in order to match it with government priorities;

- a better exchange of information among donors and between donors and governments;

- allocation of research programs to donors for funding;

- ensuring that donor-funded projects fit into the national research system;

- avoiding repeating past mistakes which have resulted in uncoordinated free-standing, donor-assisted projects;

- monitoring program progress and the extent to which donors have fulfilled their obligations in the implementation of the national research program.

Training of research and support staff, which is so crucial to the execution of the national research program, requires rationalization. Because national university post-graduate programs are weak, the majority of national staff are currently trained outside their countries, sometimes in environments very different from where they work. The national research systems need to be assured of training funds each year.

- NARS should institute an efficient system to identify trainees in accordance with priorities of the national research program.

- Donors should commit funds specifically for training in agricultural research rather than as part of the general training fund.

- Governments should devise terms and conditions of service with adequate incentives for promotion and retention of qualified personnel.

- Donors should seriously consider strengthening post-graduate schools in national universities so that increasing numbers of research scientists are locally trained.

- Donors should agree to award fellowships for training in third-country universities where curricula, problems, and research programs are relevant to the NARS being assisted.

Each donor agency has its own system of finances and procurement, as well as monitoring, evaluation, and reporting research projects. These procedures are so varied that they overwhelm the national research system. Donors should agree to simplify and harmonize these systems.

Conclusions

The problems of sustaining development in sub-Saharan Africa are numerous and must be tackled simultaneously to reverse the worsening trends, especially in the agricultural sector. National governments must act in those aspects which are within their ability to rectify. The international community must play its part to ensure that African governments achieve the desired objectives.

Agricultural research could play a crucial role in realizing the multiple development objectives of sub-Saharan Africa. National governments must enhance this potential by creating an environment conducive to agricultural research through restructuring and improving NARS management, and increasing resources to enable NARS to perform efficiently and effectively. NARS must, on the other hand, deliver the goods by addressing themselves to priority programs commensurate with national development objectives, undertaking quality research, continuously upgrading the skills of their staff, and motivating their workers.

Donors should, on their part, consider themselves as partners in the strengthening of national research capacities. They should tolerate deficiencies in NARS, fund projects of high priority, utilize technical assistance judiciously only in essential areas, allocate more resources to training, appreciate that research programs take a long time to mature and yield usable results, and restructure their aid policies to facilitate long-term assistance.

They should, as a group, harmonize their reporting systems and other management procedures for the projects they assist with each other and with those prevailing in the national systems. Finally, a mechanism should be established for donor coordination to facilitate frequent exchange of information among donors and between donors and governments.

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Information and Cooperation among National Agricultural Research Systems (NARS), and between NARS and International Agricultural Research Centers: Problems and Prospects

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This paper uses sub-Saharan Africa as an example of the relationships and cooperation between national and international agricultural organizations. After an outline of the main characteristics of national agricultural research systems (NARS) in this geographical area, the paper analyzes the Senegalese Institute for Agricultural Research (ISRA), and describes how it interacts with other NARS and the international agricultural research centers (IARCs). Avenues of cooperation are suggested, using the Senegalese experience as a reference.

African agricultural research has undergone considerable analysis during the last few years, especially under SPAAR (Special Program for African Agricultural Research). Important documents have been published by the World Bank (1987) and by ISNAR (Casas, 1987).

National Agricultural Research Systems in Sub-Saharan Africa

Since 1960 many newly independent countries in sub-Saharan Africa, with support from national research centers, universities, or both, created national agricultural research systems. Most countries have emphasized training for their national research scientists. The number of national and expatriate research scientists is steadily increasing; in 21 of the 24 countries comprising West Africa, the number has risen from 1006 in 1970, to 1458 in 1975, 2687 in 1980, and 3414 in 1985 (including 700 expatriates, about 20%).

But these scientists often lack adequate technical supervision, in some cases are a bit isolated, do not have attractive professional status or an evaluation system, and are not provided with adequate equipment. As a result, efficiency remains uncertain, and the best scientists are tempted to leave.

The West African countries have accepted enormous financial sacrifices in the name of research, but national resources are still scarce (Table 1). Foreign aid grew considerably, from US$ 124 million in 1976, to 247 million in 1980, and 307 million in 1983 (in 1988 dollars). In 1983 the main donors were (in US$):

France	81 million
USA	60 million
CGIAR	45 million
UNDP/FAO	35 million
IBRD	+ 26 million

An overall analysis of weaknesses in national research systems points mainly to:

- a lack of research planning;
- insufficient financing;
- an imbalance between operating, capital, and personnel costs (often more than 80% of the budget is allocated to personnel). Scientific equipment is not replaced, grows obsolete, and is often poorly maintained;
- irregular national funding;
- a lack of flexibility in the administrative management of research services;
- a lack of scientific experience and, in some cases, little training for research staff. Insufficient scientific supervision retards scientific development;
- irregular application of research results.

Cooperation among National Research Systems

Research cooperation is fostered by networks formed by various national research systems for work on crops such as rice, maize, groundnuts, and cassava; on drought resistance as part of CORAF (African-France Research Conference); and on economic cooperation in a region, such as the CEPGL countries (Economic Community of the Great Lakes Countries: Burundi, Rwanda, and Zaire). These networks operate mainly in French.

Table 1. Expenditure for Research in Twenty-Four Countries of West Africa (1984 or latest data av.ilable)

Country	Total spent on agricultural research ('000 current US$)	Foreign aid ('000 current US$)	National and expatriate research scientists	Expatriate scientists (from previous column)
Benin	1,583	332	58	3
Burkina Faso	9,255	8,098	126	60
Cameroon	18,939	9,696	225	65
Cape Verde	120	100[b]	16	8
Chad	752	496	29	20
Central African Republic	4,200[a]	3,600[b]	54	41
Congo	5,500[a]	3,400[b]	94	14
Côte d'Ivoire	39,600	24,235	254	180
Equatorial Guinea	NA	NA	NA	NA
Gabon	2,642	1,300[b]	38	12
Gambia	NA	NA	28	7
Ghana	4,000[a]	2,800[b]	263	12
Guinea Bissau	NA	NA	NA	NA
Guinea	NA	NA	35	NA
Liberia	1,650	1,200[b]	45	7
Mali	7,555	4,911	268	38
Mauritania	NA	NA	11	10
Niger	3,144	1,528	68	35
Nigeria	181,000	1,000[b]	1,196	24
Sao Tome	NA	NA	NA	NA
Senegal	17,850	12,139	283	119
Sierra Leone	1,393	1,000[b]	66	8
Togo	2,777	1,075	58	14
Zaire	5,874	3,000[b]	199	24
Total	305,985	79,910	3,414	701

NOTE: Except for entries marked *a* and *b*, data in the first two columns are from an unpublished IFPRI report by Peter Oram (1986).

Data for the last two columns are from World Bank (1987).

a. IBRD/WAARR mission report: collected in recipient countries in 1985.

b. IBRD/WAARR mission report: estimated on the basis of partial information collected in recipient countries in 1985.

The SAFGRAD network (Semi-Arid Food Grain Research and Development) organizes cooperation between OAU countries (Organization of African Unity) in both French and English. The newest network is RESPAO (a network to study production systems in West Africa). IDRC (International Development Research Centre, Canada) finances many research networks. It is important to realize that the cooperative research networks rely on both bilateral and multilateral foreign funding to survive. Foreign aid is also vital to support information exchange between NARS in sub-Saharan Africa.

Cooperation between National Systems and International Centers for Agricultural Research

Most cooperation involves exchange of plant materials, training for scientific and technical research staff, dissemination of scientific and technical information produced by international research centers, seminars, and conferences. Joint trials are conducted on high-yielding, disease- and insect-resistant cultivars by national systems working with IARCs. Last, international centers are able to better align their research programs with the priorities of national systems by appointing national experts to their boards of trustees.

History of the Senegalese Institute for Agricultural Research (ISRA)

ISRA was created in 1975 to administer all the agricultural research stations in Senegal. Its budget and scientific staff grew steadily until 1985, and then dropped sharply, especially in 1987 (Tables 2 and 3). The personnel budget was substantially reduced, accompanied by important staff cuts, both national (nearly 4% of the scientists, 20% of the research technicians, over 54% of the administrative staff, over 25% of the technical support staff, and over 37% of the agricultural and unskilled laborers), and expatriates (nearly 44%). Such sharp financial and personnel reductions had serious effects on the research program. Insufficient scientific supervision of the ISRA scientists is demonstrated by their few publications in scientific journals, considered as a indication of scientific productivity. Problems of staff management and inadequate career opportunities encourage the more dynamic scientists to abandon Senegalese agricultural research.

Cooperation between ISRA and IARCs

Relations between the Senegalese agricultural research system and the CGIAR (Consultative Group on International Agricultural Research) date back to the early 1960s, when it was established. At that time, and until 1974, contacts were carried out via France, which controlled Senegal's agricultural research.

Table 2. The ISRA Budget (Millions of French Francs)

	Operating costs	National staff	Expatriate staff	Invest-ments	Total
1975-76	10.48	15.02		0.36	25.86
1984[a]	32.30	31.86	32.60	13.58	110.34
1985[b]	41.11	54.96	33.86	28.37	158.30
1987[c]	39.37	28.62	26.88[d]	23.74	118.61
1988	29.31	28.40	28.80[d]	12.08	98.58

a. Starting in 1984, the ISRA budget followed the calendar year.
b. National staff were reclassified.
c. National staff were reduced.
d. Estimated on the basis of 480,000 FF per expatriate.

Table 3. ISRA Research Staff

Scientists	1975	1976	1984	1985	1987	1988
Nationals	25	30	104	131	116	116
Percent nationals	27.8	28.6	53.0	56.7	67.4	65.9
Expatriates	65	75	92	100	56	60
Total	90	105	196	231	172	176

ISRA, from the time of its creation in 1975, actively cooperated with the IARCs. Official relations were established with ICRISAT (millet); IRRI, WARDA, and IITA (rice); and ILCA (livestock). Contacts with WARDA were facilitated by the Senegalese position as a founding member and by its role in the Secretariat.

Two types of relations were established with IRRI:

- personal relationships between scientists which led to exchanges of scientists;
- official relations, with training for Senegalese staff assigned to WARDA.

These types of relationships have expanded. ISRA, in one way or another, now works with all 13 CGIAR centers except ICARDA and CIAT, and with the system as a whole:

- From 1978 to 1984 Senegal participated in the annual CGIAR meetings as regional representative for West Africa.
- The late Louis Sauger was a member of TAC in the early 1970s.
- Djibril Sène was a member of the ICRISAT Board of Trustees from 1974 to 1980.
- Several Senegalese have worked on CGIAR impact and prospect studies.
- Several Senegalese have participated and are still participating in CGIAR ad hoc work groups such as the Task Force on Sub-Saharan Africa of SPAAR.

WARDA – West Africa Rice Development Association

Initial contacts were made in 1971, when Senegal was a founding member. Formal contacts led to a protocol for a headquarters agreement. The ISRA/St. Louis section accommodated the WARDA irrigated rice research station, including offices, laboratory, and test fields. Between 1980 and 1988, four counterpart scientists in agronomy, genetics, entomology, and weed control were seconded to WARDA.

ISRA has participated in WARDA decision-making bodies. M. Toure is on the newly structured Administrative Council until 1991, and the Scientific and Technical Committee included D. Sne until 1974, and M. Toure from 1981 to 1987.

ISRA participated in varietal and agricultural trial networks with WARDA and other NARS from 1973-1980, and from 1980-1983 with WARDA, IRRI, IITA, and other NARS. Plant material has been exchanged, including Glabberima rice varieties, and rice varieties upgraded by ISRA in the varietal trial cooperation network have been introduced.

Between 1973 and 1988, nearly 100 Senegalese technicians were trained at WARDA; two-thirds attended courses lasting an average of six months. ISRA research scientists often help conduct WARDA training sessions.

In the future it would be advisable to redefine scientific cooperation with a focus on irrigated and lowland rice. A multidisciplinary, multi-institution team should be organized to include IRRI, SAED, ISRA, etc.

ILCA – International Livestock Centre for Africa

Contacts were established in 1975. ISRA scientists are involved in cooperative research networks on small ruminants, trypanotolerance, agricultural and agroindustrial by-products for animal feed, animal traction, and agroforestry. ISRA scientists help define ILCA programs, and ILCA scientists provide support for ISRA programs with methodology and evaluation work (e.g., the food program evaluation), and under the agroforestry network, plant material is exchanged.

ILCA offers grants for short, high-level training opportunities, such as laboratory training or scientific study tours, which have made it possible for Senegalese scientists to process their animal husbandry data at Nairobi and Addis Ababa. ISRA scientists serve as supervisors for training sessions organized by ILCA. The two institutes together organized training sessions in Dakar.

ILCA does not finance any ISRA program directly, but the trypanotolerant cattle research program in Senegal and Gambia receives an EEC subsidy administered by ILCA. Dr. P.I. Thiongane is a member of ILCA's Board of Trustees and the Program Committee (1985-1991). Dr. A.K. Diallo was a member of the Board of Trustees from 1978 to 1984.

ILRAD – International Laboratory for Research on Animal diseases

Firm intentions to work together notwithstanding, scientific relations are still limited to training for ISRA scientific and technical staff. ILRAD does not provide any subsidies or material assistance to ISRA. Since Mr. Toure left the Board of Trustees, ISRA is no longer represented at ILRAD. There are several possibilities for cooperation in parasitology, especially relating to trypanosomiasis, heartwater, and training on immunology methods.

CIMMYT – International Maize and Wheat Improvement Center

ISRA's relationship with CIMMYT began in 1975 when the two organizations began exchanging wheat germplasm, and continues today as part of the OMVS/FAO/ISRA program. They began to exchange maize in 1978, and ISRA has been able to adapt and create several varieties. CIMMYT has cooperated on analytical and methodological work related to genetics and biotechnology, as well as offering other scientific support and information missions. CIMMYT scientists helped implement and evaluate an ISRA rainfed maize program, and ISRA scientists have participated in various regional meetings organized by CIMMYT. A research assistant helped with training on production.

IITA – International Institute of Tropical Agriculture

This institute is one of the pillars of cooperation with the IARCs. Although not yet formalized, cooperation centers on improving root and tuber plants, especially cassava and sweet potatoes, cowpeas, and to a lesser extent, maize. IITA has offered short training sessions for 28 scientific and technical staff, as well as documentation and information sharing.

Special attention should be given to testing and introduction of Senegalese plant material, especially cowpeas, in the IITA gene pool program. In the future, ISRA and IITA intend to sign an interinstitution agreement, and to carry out a joint program funded by Belgium on mealy bug damage to cassava. An IITA scientist will be seconded to ISRA.

ICRISAT – International Crops Research Institute for the Semi-Arid Tropics

Cooperation with ICRISAT is relatively old. In the beginning it focused on varietal improvement and the phytopathology of millet, but has expanded to include sorghum, and soon will also cover groundnuts, especially aflatoxin. As part of scientific cooperation on millet, Dr. Gupta was sent to Bambey for five years. His work on varietal improvement should serve as an example. Since 1980, 40 ISRA technicians working in cereal and legume research programs have participated in six-month training courses at the ICRISAT Center near Hyderabad. The establishment of the ICRISAT Sahelian Center in Niamey will provide added thrust to this cooperation.

IRRI – International Rice Research Institute

Up until 1981, ISRA's relationship with IRRI was strong, especially in work on the chemistry of submerged soils and varietal improvement. These relations were based on personal contacts and have now waned.

ISRA participates in the IRTP network (operated by WARDA, IITA, and IRRI), and in the dissemination of documents. Chances for direct cooperation are good, but may be overshadowed by the reactivation of the WARDA programs. It may be possible for ISRA, WARDA, and IRRI to carry out a joint program on irrigated rice.

CIP – International Potato Center

Scientific and technical cooperation between CIP and ISRA centers on two activities: varietal improvement to stagger potato production, and organizing training on potato production and research for technicians from the subregion, an activity started in Senegal nearly three years ago.

CIP and ISRA have prepared a protocol agreement to enhance their future cooperation. Plans are underway for a joint program, funded by Belgium, on the improvement and propagation of potatoes throughout the dry intertropical zone. A CIP scientist will be posted to ISRA.

IBPGR – International Board for Plant Genetic Resources

Cooperation between ISRA and IBPGR will increase the conservation of plant genetic resources by rehabilitating and equipping the cold storage chamber at Bambey. Ten million CFA francs have been allocated to ISRA for this purpose. Technicians will learn conservation methods, and the organizations will share information and documentation.

There are considerable opportunities to strengthen and expand cooperation. Scientific support would be most useful at ISRA in the collection and evaluation of genetic resources, including fodder and woody species; and conservation and protection using modern methods, especially in vitro culture. ISRA, working with ORSTOM and the University of Dakar, is creating a biotechnology center which should emphasize vegetable crops and woody species. As members of the Board of Trustees, D. Sne (1980-1986) and M. Toure (1988-1991) stimulate cooperation.

IFPRI – International Food Policy Research Institute

ISRA and IFPRI have been in contact since 1983. Both institutions are interested in research on food policy in West Africa. A joint program, financed by USAID (1988-1991) provides for the assignment of an IFPRI scientist to ISRA (already posted), and training for two ISRA scientists.

ISNAR – International Service for National Agricultural Research

ISRA and ISNAR first interacted in 1983 when ISRA requested ISNAR to carry out a study on the development of human resources in relation to the Research Project. The study began in 1987, when ISNAR resources were made available. Financed by USAID, it will be completed by 1990, and will form part of the ISRA five-year plan, and will cover the development and management of all personnel categories.

During this same period, ISNAR is to research the relationship between ISRA and its environment (one junior scientist is to be based at ISRA for 12 months), and financial structures and mechanisms used by ISRA funding agencies. Prospects for cooperation between ISRA and ISNAR are very good; ISRA is considered as a model for the development of national research systems in West Africa.

Two avenues of cooperation need to be explored: in training, ISRA could serve as a backup and use its expertise to participate in ISNAR training programs; and in research, cooperative work on the organization of research systems and scientific and financial management procedures, the development of human resources, and planning and budget preparation procedures.

ISRA has been involved in ISNAR meetings and workshops since 1985, and J. Diouf was a member of the first ISNAR Board of Trustees.

Conclusions

Relations between ISRA and the IARCs are varied. The level of the relationship seems to depend on the IARC mandate, the geographical location, and the quality and intensity of personal relations. In general, ISRA has good relations with WARDA and ISNAR; an average relationship with IITA, ICRISAT, CIP, IFPRI, ILCA, and IBPGR; and a fair relationship with IRRI, CIMMYT, and ILRAD. On the whole, ISRA has made good use of opportunities for training and exchanging plant materials with the IARCs.

In the future, more positive relations can be expected with ISNAR, IFPRI, CIP, IBPGR, ICRISAT, and IITA; and relations should be reactivated with WARDA, CIMMYT, ILRAD, and IRRI (Table 4). It would be appropriate for the various centers to increase their scientific and technical support for ISRA programs, and their financial support (also for research equipment) for joint programs executed by ISRA.

Further, ISRA should invite certain IARCs to join its scientific and technical committee and thus participate in defining ISRA programs. Protocol agreements between ISRA and the IARCs should be encouraged. With this in mind, the CNRA at Bambey should become an international center for groundnuts (including food technology) and agricultural machinery (for the Sahelian zone).

Recommendations for Cooperation between NARS and IARCs

The main purposes of NARS-IARC cooperation should be:

- to improve the quality of personnel assigned to NARS by helping scientists avoid isolated working conditions and providing them with proper scientific and technical

Table 4. Summary of Current Relations between ISRA and the IARCs

Description	IARC concerned
Training ISRA staff	CIMMYT, IBPGR, ICRISAT, IFPRI, IITA, ILCA, ILRAD, WARDA
ISRA participation in training organized by, or together with, an IARC	CIP, ILCA, WARDA
Posting IARC scientists at ISRA	ICRISAT, IFPRI, CIP and IITA (both planned)
Posting ISRA scientists at an IARC	WARDA
IARC financing for an ISRA program Joint IARC-ISRA program	IFPRI (USAID funding)
Administering foreign funding for ISRA	ILCA
Scientific or technical equipment for ISRA	IBPGR
Scientific or technical backup at ISRA (analyses, methodology, leadership, evaluations)	CIMMYT, ILCA
ISRA participation in defining IARC programs	ILCA
IARC participation in defining ISRA programs	-
ISRA participation in meetings organized by IARCs	CIMMYT, ISNAR
IARC participation in meetings organized by ISRA	CIP
Studies on ISRA by an IARC	ISNAR
IARC section based at ISRA	WARDA
Joint ISRA-IARC research trials	ICRISAT, IITA, ILCA, WARDA
ISRA-IARC exchange of plant material	CIMMYT, CIP, ICRISAT, IITA, ILCA, WARDA
ISRA participation in IARC executive bodies	IBPGR, ILCA, WARDA; formerly ILRAD and ICRISAT
IARC participation in ISRA executive bodies	-
ISRA-IARC information exchange	CIMMYT, CIP, IBPGR, IITA
ISRA-IARC protocol	WARDA, CIP (under preparation)
ISRA would like more active relations with . . .	CIMMYT, ICRISAT, IITA, ILRAD, IRRI, ISNAR, WARDA

supervision, which, together with ongoing training, should enable NARS to be staffed by high-level scientists qualified to meet the agricultural challenges facing their countries;

- to compensate for financial and material shortages by rationalizing and harmonizing research programs, which would require an unequivocal evaluation of the NARS and a national decision to combine forces (unified programs should be supported by centers carefully selected in the various ecological zones and properly equipped through support from international aid);

- to ensure adequate dissemination of scientific and technical information on current research programs and results.

Rather than reviewing all the actions that should be launched, let us stress the main lessons from experience accumulated in the IARCs during the last 25 years. First, the NARS evaluation should be continued, maximizing on ISNAR's experience. This diagnosis is crucial to evaluate the real problems that NARS must face, and to decide on the best remedies.

An effective way to improve the quality and efficiency of NARS personnel would be to organize frequent small meetings for scientists on specific themes.

In an effort to provide better scientific supervision, senior NARS scientists, either nationals or expatriates, should be motivated to stay on the job. When selecting expatriates, more attention should be given to their past research experience, without, however, excluding young scientists. The tendency to hire young expatriates who acquire experience and then immediately leave the NARS should be changed.

Further, scientists could work more efficiently if they were supported by an adequate number of qualified managers and technicians. Priority should be given to training good maintenance technicians for scientific and technical equipment. Resources could be used more expediently if joint programs were designed for NARS and IARCs, with special attention to the development of central bases within NARS. If foreign aid provided adequate material and financial resources, these bases could turn into centers of excellence in their particular fields. These bases, of course, should have access to well-stocked data bases. As part of the Sahelian agricultural development, the Senegalese National Agronomy Research Center (CNRA) in Bambey could be developed into a center of excellence for groundnuts and agricultural machinery. Further, special attention should be given to setting up gene banks and promoting biotechnology laboratories to be shared by several NARS.

Last, the agricultural scientist must change his attitude, and work harder on disseminating scientific and technical information, for example by teaching and using mass media. Modern communications should serve to make producers, planners, and the public at large more aware of the true value of research. It would be well worthwhile conducting bona fide research on the techniques of disseminating scientific and technical information on agriculture.

By further developing cooperation, NARS could perform better. We are convinced that the IARCs can only reach maximum efficiency if they receive support from NARS serving as strong relays that harmoniously combine research, education, and extension work.

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Private-Sector Participation in Agricultural Research and Development: Notes on Issues and Concerns[1]

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Introduction[2]

Scientific discovery and the resulting innovative technological processes are probably the most important elements in 20th century civilization. In agriculture, new cultivars and capital inputs have not only augmented yields and production, but also dramatically transformed agricultural societies and the well-being of individual groups. On the other hand, the pervasive, profound, and quite frequently asymmetric impact of technical change on the economic and social organization of society has increased the preoccupation with the development of mechanisms to control the direction and intensity of technical change.

In Latin America, and probably elsewhere in the less-developed world, discussion has mainly revolved around the creation of national research institutions that could guarantee adequate state participation in the production of agricultural technology. However, the economic and institutional developments in these countries during the past two decades have spawned private and semi-public organizations that are active in specific aspects of technology generation and transfer.

In market economies, the development of nonpublic research institutions is an integral part of the agricultural modernization process. This development is determined primarily by the formation of necessary preconditions related to the demand for technological inputs, production organization, the appearance and organization of social sectors with economic interests in technical change, and the growth of technological potential. In the last decade, these elements have been reinforced by the emergence of biotechnology, which changed not only the scientific base of agricultural research and development, but also the nature of the resulting technologies and the institutional context of the technological process in agriculture.

This scenario has profound implications for both the policy and organizational dimensions of national agricultural research and development systems, and the capacity of developing countries to fully exploit the potential of science and technology for agricultural development and economic growth. Here, we review some of the main forces behind the growth of the private sector in agricultural research and technology development, then discuss the new institutional situation, primarily in Latin American. However, since the basic forces behind this process are phenomena of a generic nature (for example, the role of technological development in market economies), the discussion could also be relevant to other regions of the developing world.

Agricultural Modernization and Institutional Change

The nature of the technology has important implications for the relative role of the public and private sectors in technology development. In the early stages of development, the quasi-monopolistic role played by public research institutions is practical – only the state could absorb the costs of research. These initial costs are

- relatively high because there is a shortage of trained personnel and an adequate research infrastructure is missing;
- risky because basic knowledge is lacking and markets are inadequate, etc.;
- difficult to recover.

Under these conditions, agricultural technology can be seen as a pure public good, and the institutional model that emerged assured the supply of technology and socialized research costs. The problem was viewed as one of transferring technologies from developed to developing countries, which required an infrastructure capable of adapting available technologies to local conditions. This formed the conceptual basis for international assistance that supported the development of public research institutions, usually following the US land-grant model.[3]

As agricultural modernization progressed over the last three decades, a number of changes set the basis for increased interest and participation by the private sector in agricultural research and technology development.

The public-sector role in the development of research infrastructure and human resources

The initial efforts of national agricultural research systems (NARS) in Latin America, as well as in other parts of the world, were oriented toward human and natural resources as well as other information considered essential for applied and adaptive research. Work in both of these areas was undertaken with extensive funding and technical support from the international donor community (Trigo, 1986). The result was a dramatic increase in the availability of adequately trained personnel and a widening of the information base for applied research activities.[4] Both aspects affected the costs of research and development (R & D) activities for the private sector. Private firms interested in developing R & D units preferred to hire researchers away from the public sector. This process was facilitated by the salary restrictions in public research institutions and universities.[5] At the same time the increased basic agricultural knowledge also lowered the risks associated with R & D, and even made possible work in other areas such as agrochemical evaluations and fertilization.

Producer and nongovernmental organizations in technology generation and transfer

Technology has become more important in the production decision-making process in both the public and private spheres. In general, as the availability of previously unused land diminishes, technological change becomes the only means of increasing production. Moreover, the increased use of non-neutral technological inputs, in terms of their effects on income distribution, has affected the direction and intensity of technological change.

Cooperative agricultural producer organizations and, more recently, nongovernmental research foundations, have become important actors in the agricultural R & D process. Producer organizations are important in cases where production is homogeneous and where the technological potential already exists.

The rice and sugarcane growers' associations in Colombia are good examples of how producer groups increasingly participate in technology development. In the case of rice, research and transfer activities began in the 1950s at the Colombian Agricultural Institute (ICA), but initiatives and responsibilities were gradually transferred to FEDEARROZ as this organization consolidated and developed its technical capacities. After CIAT (Centro Internacional de Agricultura Tropical) initiated its rice activities in the early 1970s, creating substantial "technological potential", the direct participation of FEDEARROZ became of real importance in a triangular partnership with CIAT and ICA. The case of sugarcane is somewhat different, because the sugarcane trade association (formed mainly by the sugar-mill owners) created an independent research center with ties to the public system through the participation of government representatives on its board. This center (CENICANA) is now formally mandated to undertake all sugarcane research in the country (Samper, 1982).

The influence of farmer organizations extends well beyond cases of direct participation in research activities. As their institutional and technical capabilities consolidate, they have also played an increasing role in setting the research agendas of public institutions (dairy products, soybeans, maize, and palm oil in Ecuador) and in funding research activities (National Maize Committee and National Cotton Fund in Peru, wheat and cocoa in Colombia, industrial tomatoes in the Dominican Republic and Panama, and the multicommodity case of the Patronato de Sonora in Mexico) (Barsky, 1985; ISNAR, 1983; Paz and Planas, 1985).

Producer organization involvement in the adaptation and dissemination of technology has also become significant. In some cases, producers have virtually assumed the role of the public extension system through the development of their own technical assistance mechanisms. Following the model developed by the French Consortia for Agricultural Technology Experimentation (CETA), the CREA groups in Argentina exemplify this trend. First created in the late 1950s, the CREA model spread quickly during the following decade, and became especially strong in the 1970s. In the early 1980s in Argentina, there were about 150 local groups with more than 1500 individual members. The model has spread to other Southern Cone countries, notably Chile and Uruguay, and there are indications of similar initiatives in a number of other countries of the region (Martinez Nogueira, 1985).

Another important institutional development is the research foundation. Within this group, it is necessary to distinguish between those mandated to perform research themselves and those that fund research undertaken by other public and/or private research organizations.[6] FUSAGRI and FUNDESOL in Venezuela, the Fundación Hondurea de Investigación Agropecuaria – FHIA in Honduras – and Fundación Chile are cases of the first type. Even though each responds to a particular situation, all were created to mobilize technological knowledge with a problem-solving orientation, and a highly flexible, nonbureaucratic administrative structure. Although applied research is the core activity, they have very strong transfer programs, and organizations such as Fundación Chile go as far as the design and implementation of agroindustrial projects to exploit specific production potentials or market opportunities. Research funding foundations are more recent, and are still in the development stage. The Fundación Dominicana de Investigación Agropecuaria in the Dominican Republic and FUNDAGRO in Ecuador belong to this group. In most cases, these foundations develop as external donors seek to provide alternative sources of funding, but they still must consolidate operations and prove their long-term financial viability. Most depend on external donor grants (primarily USAID).

Regardless of whether they perform R & D activities themselves or are restricted to funding research, the foundations are important because they add to a country's research capability, as well as widening the research support base. Potentially, they can fill two critical niches in the process of technology generation and transfer.

The first is the need to link technology generation with technology utilization, something that public institutions have not done efficiently. This is particularly important for agroindustrial crops, but is also proving critical for food crops, as some of the FUSAGRI experiences in regional development show.[7] Second, they provide an institutional "bank" for private-sector resources to support research. Improved technology is increasingly recognized as a critical input for agricultural development, but in most cases the domestic private sector lacks the economic size to directly undertake needed R & D activities. Because of their bureaucratic image and bad track record, pubiic-sector organizations are not an attractive alternative as direct recipients of private-sector funding. In this context, research foundations could provide an ideal base for project development and monitoring, with the research itself conducted by either the public-sector centers, universities, or other research institutions.

Development of markets for technological inputs

Agricultural modernization implies a substantial modification of market incentives for private participation in technology generation and transfer. The most important modification is the opening and widening of previously nonexistent or very limited markets for technological inputs. Several factors are interrelated. First, there is the tendency for seeds, agrochemicals, and machinery to become more important in relation to agronomic practices as sources of productivity growth. Then there is the rapid growth of commercial agriculture as compared to the traditional sector, probably as a consequence of its better access to credit and technical assistance. Together with the growth of the commercial sector, modernization also develops the communication and service infrastructure necessary for getting new inputs to the farm, thus expanding the markets for these inputs even further.

The incentives for private participation in R & D activities are market growth and lower input distribution costs (lower level of investments and shorter payback period). This is further reinforced by property protection, which the passage of plant breeders' rights legislation in a number of countries has extended to seeds, while agrochemicals, machinery, and veterinary products are protected by the patenting laws regulating the industrial and pharmaceutical sectors. Under these circumstances there has been rapid growth in these industries.[8]

This is neither new nor unique to Latin America. The experience of the United State indicates a similar trend in the change from what was initially a primarily public system, implemented through the creation of the land-grant colleges and the US Department of Agriculture experiment stations, to the present situation, where about half of all agricultural research is funded by private firms.

In Latin America, and probably in other less-developed regions, this process has gone beyond what regional and national conditions warrant. This is largely due to the increased importance of multinational firms. Their multinational character has relaxed some market constraints because technological knowledge and innovations developed in one country can be used in another. The integration of national firms into multinationals also implies differential access to technological potential -- the larger scale of operations permits their direct participation in the generation of new basic knowledge (Trigo and Pineiro, 1981).

Another important form of private R & D and technology transfer is through the activities of agroindustrial complexes, usually working in industrial crops and high-value aggregate products. In many cases, these firms develop their own R & D units and technical assistance systems to assure a continued supply of raw materials that meet their specifications (de Janvry et al., 1987). Examples include the following:

- the dairy industry in Argentina, where the large co-ops (SANCOR) and some private firms like La Serenisina have taken over almost all R & D functions, including technical assistance to farmers;

- in Venezuela, PROTINAL (an animal feed concern) has taken over variety development for sorghum, and the POLAR group (maize milling) has created its own experiment station to develop soybeans and maize varieties. In both cases, the initial R & D efforts led to the creation of seed companies to market the products that were first developed for in-house raw material needs.

Vegetables and strawberries in Mexico are also important. However, in this situation, R & D was provided by the transnational corporations that exported fresh or frozen produce to the US market.

A number of more recent initiatives in pineapples and other fruits in Central America developed as part of the Caribbean Basin Initiative, an export promotion program of the US government to facilitate exports from that region to US markets. This form of participation can be expected to increase substantially as the proportion of agricultural production subject to processing before reaching its final market becomes higher, and as efforts to diversify agricultural exports and increase their value-added content are intensified.

Biotechnology and the Privatization of Agricultural R & D Activities

Biotechnology is significantly changing the scientific and institutional basis of agricultural technology generation and transfer.[9] Several aspects are important for developing countries. The first is that biotechnology is radically different from previous technologies because, for the first time, commercially relevant technical information is at or close to the frontiers of basic research in molecular and cell biology.

This is changing the traditional dichotomy between basic and applied research and altering linkages in the flow of scientific information. Work is now being done in biotechnology by universities and research centers with no previous experience in agriculture.[10] Such a shift poses a significant problem for national research institutions in Latin America and the Caribbean, which have no links with these new centers of valuable technological information. A related problem is that biotechnology requires scientific talents different from those available at the traditional agricultural institutions. Eventually, the greatest obstacle preventing developing-country research institutions from participating in biotechnology may be that few of their staff are trained in molecular and cell biology, virology, and immunology (de Janvry et al., 1987; IICA, 1987).

A second important facet of biotechnology is its relationship with the private sector (de Janvry et al., 1987). During the Green Revolution, most essential components were handled through public (international or national) institutions, whereas biotechnology in the private sector, prompted by the proprietary nature of resulting technologies, is already an important force and will probably increase. Even though universities are playing an important role, the development of biotechnology in industrialized countries is characterized by market incentives and massive private investment, both from multinational corporations and from venture capitalists supporting small biotechnology firms. Private-sector involvement today is underscored by about 300 firms actively working in the field in the United States, 150 in Japan, and about 100 in other countries. Monsanto and Dupont, two of the large corporations most active in this area, have invested $150 million and $80 million, respectively, in building state-of-the-art biotechnology laboratories (Riggs, 1985; Lohr et al., 1986), and many other corporations are involved in many different sectors of the biotechnology industry (Table 1).

It is not easy to assess the possible impact of biotechnology on Third World agriculture. Table 2 highlights an additional characteristic of biotechnology that sets it apart from the traditional approach: it is not product specific. Technology has traditionally been product specific, which was a key factor in shaping the organization of agricultural research and technology. Biotechnology, on the other hand, is *process* based and cuts across products. This will strengthen private participation in agricultural R & D as numerous factors change the industrial organization of the agricultural input business, with greater participation by transnational corporations. This is important for the development of national strategies in this field (de Janvry et al., 1987; IICA, 1987).

Table 1. Numbers of US Companies in Specific Technologies and Markets

Technologies	Markets												
	AG	BL	BM	CM	DG	EN	FP	FU	MN	PS	PH	TW	VT
Cell culture	70	113	15	41	110	17	33	16	6	26	86	11	76
Cell fusion	48	104	8	32	111	8	23	9	3	19	67	7	60
Fermentation	60	81	28	53	63	22	42	19	6	27	73	18	46
Enzymology	44	71	16	41	60	14	34	10	4	22	55	12	40
Process control	17	23	5	19	20	4	9	3	0	9	24	3	14
Purification	46	94	16	51	87	14	31	9	1	18	73	10	52
Recombinant DNA	58	87	16	44	80	17	33	15	4	28	70	17	52
Gene synthesis	8	11	3	4	11	2	3	3	3	4	13	3	8
Large-scale purification	35	73	10	36	60	8	26	6	1	16	60	7	35
Separation	45	79	12	43	74	11	31	8	2	17	66	9	45
Sequencing	22	32	3	22	28	6	13	4	1	10	29	4	15
Synthesis	27	45	5	33	41	8	14	3	0	15	39	4	26
Total expenditure (US$)	110	181	34	88	178	31	66	27	8	42	140	25	106

SOURCE: Riggs (1985), as cited in de Janvry et al. (1987).
AG = agriculture; *BL* = biologicals; *BM* = biomass; *CM* = chemicals; *DG* = diagnostics; *EN* = energy; *FP* = food processing; *FU* = fuels; *MN* = minerals; *PS* = pesticides; *PH* = pharmaceuticals; *TW* = toxic waste processing; *VT* = veterinary.

Table 2. Markets and Biotechnologies Relevant to Food Systems

Technologies	Markets												
	AG	BL	BM	CM	DG	EN	FP	FU	MN	PS	PH	TW	VT
Bioprocessing		x	x	x		x	x	x	x	x	x	x	
Genetic engineering	x	x	x	x	x	x	x	x	x	x	x	x	x
Ecological engineering	x		x									x	

SOURCE: Riggs (1985), as cited in de Janvry et al. (1987).
AG = agriculture; *BL* = biologicals; *BM* = biomass; *CM* = chemicals; *DG* = diagnostics; *EN* = energy; *FP* = food processing; *FU* = fuels; *MN* = minerals; *PS* = pesticides; *PH* = pharmaceuticals; *TW* = toxic waste processing; *VT* = veterinary.

The Privatization of Research and Technology Development

The trend is for the private sector to be more involved in agricultural R & D activities. In addition to institutional and market-force changes associated with the modernization process, biotechnology and more exclusive patenting criteria have reinforced and broadened the trend. All these factors have definite policy and organizational consequences for the systems of national agricultural research and technology transfer. In the remainder of this section, we briefly discuss some of the issues emerging from this process. However, neither the list nor the treatment is exhaustive, as the process is still evolving; many of the possible consequences or elements discussed are still hypothetical, and we lack sufficient information for an in-depth analysis.

The privatization of knowledge

The increasing participation of the private sector in R & D activities and the emergence of biotechnology has important consequences for the organization of research and the free flow of scientific knowledge. As the development of commercially relevant technical information comes closer to basic research, the traditional dichotomy between basic and applied research is significantly altered, and with it the linkages for the flow of scientific information. Furthermore, the possibility of patenting research results means that an increasingly significant portion of scientific knowledge will be withdrawn from the public domain.[11]

These trends have important implications for technological institutions in developing countries. Such institutions once looked to the universities in developed countries (most notably, those of the US land-grant system) and to the international agricultural research centers for basic and strategic research results. They now find that the information they need is controlled by private companies or emerges from basic science laboratories which, all too often, have significant connections with private industry. The information is either protected by patents or subject to "industrial secret" practices because of its potential commercial value. The developing countries have no substantial ties with these companies nor easy access to them. This new "academic industrial complex" represents a significant change in the organizational structure of the systems of agricultural science and technology in the developing world (Kenney, 1986). Without easy and free access to basic, strategic scientific information, it is not clear how the NARS could continue to perform their functions. Moscardi (1988) points to two problems they must confront:

- relatively slow and increasingly costly access to new knowledge and specific technologies;

- the bias of new technologies in terms of input use and relevance for local conditions.

The latter is of special importance for tropical and subtropical areas

Activities of transnational corporations and national technological development

The modernization process and the opening of developing country markets for technological inputs not only brought private-sector involvement into R & D, but also an increasing participation by multinational corporations in agriculture and agricultural supply industries. The growth of biotechnology has reinforced this tendency. New plant breeding technologies and changing patent legislation are leading to a restructuring of the industry, integrating previously independent segments (seeds, agrochemicals, etc.) into highly concentrated multinational conglomerates.

Until the 1970s, inputs for crop and animal production were generally marketed by separate firms for each product area: seeds, chemicals, pharmaceuticals, machinery, and petroleum products. However, these input industries have been restructured, and the research process has been realigned.

The first factor in the transnationalization of the original seed companies occurred as profitable markets opened in the developing world. This developed both through the creation of subsidiaries and the take-over of already existing developing-country seed firms. The second, and probably more important, factor was the acquisition of these firms by larger ones, mainly agrochemical, oil, grain trading, and pharmaceutical companies. According to de Janvry et al. (1987), this was the result of two separate but interrelated forces.

First was the decline in the profitability of the chemical industry when energy costs and environmental controls increased during the mid-1970s. This led many of the large chemical companies to diversify and enter specialty end-product markets (Kenny, 1986). Second was the passage in Europe of legislation to secure rights for plant breeders in the early 1960s, along with the Plant Variety Protection Act in the United States in 1970. The possibility of establishing proprietary protection on genetic materials and the natural complementarities between seeds and agrochemicals at the marketing stage made seeds an obvious and optimal road for diversification for these companies (Mooney, 1979). It now seems likely that virtually all seed companies will become centerpieces of transnational corporations (TNCs).[12]

In more recent times these companies, seeing the tremendous growth of the biotechnology industry, have begun to finance biotechnology research on a contractual basis from universities and smaller start-up firms, and to invest relatively large sums in in-house R & D units.

From a general perspective, the growing importance of TNCs in agricultural technology supply industries could be seen as positive. To the extent that they are truly international corporations with research facilities around the world, the privatization of applied research may actually benefit developing countries, particularly in export markets, by giving them rapid access to state-of-the-art technology at the same time and price as everyone else. This would remove part of the advantage that developed countries have in terms of early access to new technologies, but it would also raise a number of problems (de Janvry et al., 1987).

First is a possible bias in research priorities toward the development and promotion of technological packages which reflect a global corporate strategy to integrate seeds with a company's own chemicals, rather than breed for genetic resistance to abiotic stresses, insect pests, and diseases. This will increase the dependence of agriculture on purchased inputs, which will favor larger commercial agriculture over small holders.

Second, the expansion of the TNC seed business could further narrow the genetic base of important staple crops such as maize, wheat, and sorghum, which would increase the risks of widespread crop failure in many parts of the world.

Finally, there would be broader implications of economic and food security that would result from increased dependence on TNC marketing networks for strategic technological supplies. Capital-intensive technologies may be in opposition to the prevailing economy in developing countries where natural resources and/or labor are relatively abundant compared to capital resources. At the same time, many countries will create a high "political adjustment" factor to maintain national control of the strategic factors that affect food production and agricultural exports. Furthermore, TNC's concentrate their efforts on crops and technologies for which there are markets of significant size, so many crops and problems will not be included in their R & D strategies. All these elements highlight the importance of continued development of national R & D capabilities together with clear policy definitions concerning TNC participation in national markets for agricultural supplies.

The ever-increasing need for a comprehensive national agricultural science and technology policy

The transformations discussed in the previous sections have major implications for the design of technology policies for the agricultural sector. Agricultural modernization, with its concomitant industrialization processes, converts on-farm production into an ever-smaller component of the sector. Backward (input) and forward (processing/marketing) linkages assume greater importance. The specific nature of this process may differ between places and commodities, but the general trend is usually the same: as agriculture and industry grow increasingly interdependent, agricultural production should be viewed as one phase of the agroindustrial production chain, and it becomes necessary to consider the policies that govern agriculture and technology in the context of policies that govern industry and other sectors.

The tendency toward increased private-sector participation in agricultural R & D activities also implies the passage from a relatively centralized system to a highly diversified one. This raises the issue of how to integrate diverse efforts into a coherent whole, making optimal use of opportunities and available resources.

The new biotechnologies also affect the scope of policies that govern agricultural technology. As basic science grows closer to technological development, innovations in agricultural technology need to be viewed in the broader context of overall policies for science and technology in a country. Thus, policymakers must consider agricultural research centers along with the whole complex of scientific and educational institutions.

Policies for technology in the agricultural sector have traditionally amounted to little more than decisions on resource allocation for research within the national public research institutions, with little thought given to the broader context.

In the early stages of the system, the monopoly of national research institutes implied that the direction and nature of the technological process was indirectly determined by the processes of priority setting and resource allocation in these organizations. As the importance of their role diminishes and they become but one of the alternative sources for the supply of new technologies, the direction of technological change will depend more and more on market forces.

The potential contribution of technology to agricultural development and economic growth can be fully tapped only if full consideration is given to the interdependence of different sectors and the impact that macroeconomic policies have on technological behavior in the agricultural sector.

Further information is needed on the specific ways these interactions take place. In some cases, changes need to be introduced in the processes by which policy decisions are made, so that decisions on research priorities and resource allocations will be consistent with economic and agricultural policy. This will be possible if forward-looking economic planners and private-sector suppliers of modern inputs, as well as the different research clientele groups, are incorporated into the policy-making process.

The role of public-sector institutions

With the emergence of new private sources of technological knowledge, we are witnessing a progressive deterioration of public-sector research institutions. This situation could mainly be a consequence of the budgetary restrictions derived from the debt crisis in the developing world. But it is also the result of what is perceived as the ineffectiveness of public organizations to reach farmers, particularly the smaller ones, and meet their technological needs. Under these circumstances, and if the technological process is totally subject to the rules of market behavior, the deterioration of public research institutions will continue and probably worsen, as a vicious circle of lack of impact due to operational budget restrictions and reduced support sets in.

This scenario is of particular importance in the developing world because the agricultural sector is characterized by the coexistence of productive sectors at different stages of modernization. Within this structure, increasing participation in the supply of technological services by private and semi-public sources, together with the deterioration of public institutions, implies the potential widening of existing differences. Private sources will tend to service only those in the more advanced segments with technological demands oriented to the capital inputs they offer. This is important for small-producer and peasant economies in general. With the high heterogeneity of farm types and environments, they seldom represent profitable alternatives for the private sector. Moreover, the basic structural conditions necessary to facilitate producer organizations don't exist.

In this context, it is clear that there is a need to revise the role of the public sector in the technology development process, so that it can function effectively in the new institutional and economic situation and continue to perform its service function for the non-modern sector. In general terms it seems that an appropriate division of labor would focus public-sector institutions primarily on the generation and transfer of technologies for the small farm sector, and in those areas where either the size of the markets (small regions) or the nature of the technologies (agronomic techniques, resource management research) offer no possibility to recover R & D costs. On the contrary, the private sector should be encouraged to develop technologies where the proprietary nature permits cost recovery. This broad division of labor, however, does not imply that the public sector should not continue working on basic or strategic research to assure a minimum level of technological independence at the national level.[13]

The role of the international agricultural research centers

The privatization of knowledge will also affect the ability of the IARCs to maintain their relationships with national programs. As with the national research institutions, the problems will involve linkages to the sources of basic scientific knowledge. As the IARCs took shape, most funding came from the governments of developed countries and from philanthropic foundations. IARC scientists were at the forefront in establishing a free flow of scientific information among researchers, internationally, from diverse countries — north and south, socialist and capitalist. Because the private sector showed little interest, the limited resources of IARCs and LDC governments were used to establish input distribution networks and technology transfer systems. IARC scientists released new varieties into the public domain — freely available at a nominal cost to anyone interested. Virtually all technical information was available in the public domain from research institutes in developed countries, where the basic technical concepts had long been established.

The newly emerging biorevolution is altering the institutional structure of international agricultural research in many ways. Private companies now have sufficient technical information to engage in LDC-oriented plant-improvement research. Multinational chemical and seed companies, concerned that their technology be adequately protected by patents and other intellectual property restrictions, are unwilling to share their findings with public institutions. They know that the information might at some point prove to be profitable. Private firms are pushing to extend the Plant Variety Protection Act and patent and trade-secret protection in this field, thereby forcing the IARCs to consider new strategies in response to privatization of germplasm, research processes, breeding lines, and varieties. This tendency, although stronger in private firms, is starting to show up in universities, where there is already a formal discussion about the patent rights of scientists working with public funds.

It is still not entirely clear how these factors will affect the performance of the IARCs. It is evident that if these centers are to continue providing meaningful assistance to national programs, they must revise some of their basic policies. Their relations with the private sector need to be recast, and their involvement in basic or fundamental research must be rethought in response to greater restrictions on the free flow of scientific information (Buttel, 1986).

The funding of R & D activities

These institutional developments open a key source of new funding for agricultural R & D activities. Private resources will be important to help widen the support base and free up public resources. Furthermore, in the case of heavily indebted countries, attracting private resources for technology generation and transfer represents one way to mitigate the impact of the budgetary crisis on public research institutions. Establishing a link between the public and the private sector, however, is not easy.

Many countries still lack a tradition of interaction with private-sector research and development and need institutional mechanisms for such cooperation. As a result, the private sector often finds it difficult to finance research projects in public research institutions. In turn, public-sector scientists are often prevented from participating in private-sector research and development. The pace of change in this area is very slow, in part because of a long history of mutual suspicion, but also because private firms in the developing world have not traditionally been willing to spend on R & D. To a certain extent, this is because TNCs dominate and, in many research-intensive industries, do their research elsewhere. Local firms in most cases lack experience in translating research results into production activities (Waissbluth et al., 1985). The direct transfer of technology from abroad has also tended to discourage innovation in this area.

Important initiatives have already begun to develop public-private funding linkages. One example is the case of producer associations and research foundations in a number of countries, as described earlier. More complex mechanisms, however, are needed in response to the increasingly proprietary nature of agricultural technology. Argentina recently entered this area when INTA introduced a system of joint ventures with the private sector, allowing local firms to make full use of its R & D capacity, while at the same time strengthening its own budgetary situation and allowing scientists to benefit from at least part of the commercial value of their research findings (Moscardi, 1988). However, further innovations are still needed to modernize the prevailing bottom-up planning and make it more responsive to final users. This will preserve public-sector research while enhancing the flow of personnel and financial resources between the public and private sectors. International technical cooperation has an important role to play in this process by facilitating the analysis and exchange of experiences among countries, and providing assistance to specific development projects when needed.

The importance of increased cooperation between the public and private sectors goes well beyond the funding issue. It will have a great impact on a country's ability to exploit new scientific developments, particularly biotechnology, in the field of agricultural inputs and new market opportunities related to export diversification.

In many countries, especially the smaller ones, TNCs already control input industries, and local firms are merely distributors of TNC products. The transition to biotechnology may not bring great change. Even so, independent or state-run suppliers of seed, chemicals, and fertilizer will not be able to compete unless the R & D capacity already existing in the public sector can be used to sustain their competitiveness in local and regional markets (de Janvry et al., 1987; IICA, 1987).

Effective R & D support is also the key for new export markets. Many opportunities already exist, but they could be identified and made more accessible by government activity. Without greater coordination between the public and private sectors, however, these opportunities will be lost or undertaken as part of TNC R & D efforts, and developing countries will miss the opportunity to access critical private funds for research and to exploit national innovations.

Some Concluding Comments

Over the last quarter of a century, institutions in the developing world that generate and transfer technology have grown dramatically and have had a tremendous impact on agricultural improvement and economic growth. A number of specific cases -- grains in Argentina, soybeans and wheat in Brazil, potatoes in Ecuador, rice in Colombia and the Dominican Republic, and wheat in Mexico -- attest to this process. It is also clear that in Latin America and the Caribbean, those countries that invested more on research and development are the ones that show a better agricultural performance overall (Scobie, 1977; Moscardi, 1988).

Public agricultural research organizations have been at the center of a successful technological effort. At the same time they have been major contributors to the necessary conditions that will allow nonpublic organizations to become active participants in the technological process. Scientific developments, particularly biotechnology, have produced a new institutional situation where public institutions are no longer the sole suppliers of new technological knowledge, but rather, share the stage with a large, increasing number of alternatives, particularly private industry.

Parallel to these institutional developments, the debt crisis has limited the operational capacity of national research organizations and has impaired their ability to deliver what is expected from them.

All these elements make evident the need to review the prevailing institutional model and introduce changes and adjustments, so that it can continue to meet each society's demands for agricultural technology. These changes imply a redefinition of the scope of the policies that govern agricultural technology and the role that public-sector institutions should play. There will also be a need to develop specific mechanisms to cope with issues such as the interaction between the public and private sectors, and the effects of biotechnology on the workings of national systems. It is important to stress that, even though public research organizations may have lost the quasi monopoly they maintained earlier, they are still the centerpiece of national agricultural science and technology and will continue to play a key strategic role in the process of technological change. The issue is how to adapt the model to exploit the modernization process and the diverse new participants. The latest increased availability of international technical knowledge must be utilized while retaining the capacity to direct R & D toward national development priorities and maintain a reasonable degree of social control of the innovative process.

In this paper we have advanced our views on these issues as an initial contribution to on-going analysis and discussion. We have addressed the issues in a general way, but from a perspective strongly influenced by the Latin American situation. The discussion of policies and alternatives for specific situations will of course require proper consideration of the particular agroecological and socioeconomic characteristics of each country.

Notes

1. The author wishes to acknowledge the contributions of the staff of IICA's Technology Generation and Transfer Program, particularly Jorge Ardila, Eduardo Lindarte, and Walter Jaffe.

2. The ideas and issues presented in this paper were developed on the basis of some of the author's previous work (Trigo and Pineiro, 1981; Pineiro and Trigo, 1985; Trigo, 1986), as well as the work of others such as IICA (1987), de Janvry et al. (1987), and Moscardi (1988).

3. In the Latin American context, this process created a number of research institutions that today constitute one of the region's most important assets for agricultural development. They include the National Institute of Agricultural Technology (INTA) of Argentina, founded in 1957; the National Institute of Agricultural Research (INIAP) of Ecuador, founded in 1959; the CONIA/FONAIAP complex in Venezuela, which began operations from 1959 to 1961; the

National Institute of Agricultural Research (INIA) in Mexico, circa 1960; the Agricultural Research and Outreach Service (SIPA) in Peru which, after successive modifications, became the National Institute of Agricultural Research and Outreach (INIAA) in 1984; the Colombian Agricultural Research Institute (ICA), founded in 1963; and the Agricultural Research Institute (INIA) of Chile, founded in 1964. The 1970s saw the establishment of the Empresa Brasileira de Pesquisas Agropecuarias (EMBRAPA) in Brazil, the Bolivian Institute of Agricultural Technology (IBTA), the Institute of Agricultural Science and Technology (ICTA) in Guatemala, and the Agricultural Research and Development Institute (IDIAP) of Panama. Efforts to create similar institutions are under way today in Uruguay and the Dominican Republic (Pineiro and Trigo, 1985).

4. Between 1960 and 1984 the human resource base for agricultural research in Latin America grew at an annual rate of about 6.5% per year, increasing from about 1000 researchers in 1950 to over 8500 in 1984. In specific countries the evolution followed approximately the same tendency as the region:

 - At EMBRAPA in Brazil, the total number of researchers between 1974 and 1985 grew from 872 to 1650 (an annual rate of almost 6%).

 - At ICA in Colombia, the number of researchers between 1962 and 1988 went from 137 to 603 (an annual rate of 5.9%).

 - At INTA in Argentina, the increase was from 640 researchers in 1958 to 1467 in 1978 (an annual rate of 4.2%).

 - At INIFAP in Mexico, the growth rate between 1977 and 1985 was 9.7%, when the number of researchers went from 929 to 1949.

 These figures are the author's estimates and are based on data from IICA and ISNAR publications.

5. For an extensive discussion of this process in Argentina, Peru, and Colombia, see Trigo et al. (1982).

6. For a more complete discussion of the case of the research foundations see Lindarte (1986).

7. For a detailed discussion of the case of FUSAGRI see Penango and Avalos (1986).

8. An idea of the quantitative importance of market incentives can be seen from the evolution of modern input consumption. For the whole of Latin America, the

proportion of the area sown to modern varieties grew from 11% to 83% for wheat and from 4% to 28% for rice between 1970 and 1983 (Scobie, 1987). The fertilizer consumption index between 1979 and 1985 grew at about 13% per year for nitrogen, 7% for phosphate, and 13% for potassium (FAO, 1986-1987). The net trade of pesticides increased fourfold between 1970 and 1975 (de Janvry et al., 1987).

9. The principal techniques identified as biotechnologies are cell/tissue culture, cell fusion/hybridoma production, recombinant DNA techniques, gene synthesis, separation, fermentation, enzymology, purification, large-scale purification, sequencing, and process-monitoring control (Riggs, 1985). Only cell fusion, recombinant DNA, and gene synthesis are considered genetic engineering; the rest can be termed *bioprocessing technologies*.

10. Hard evidence in this sense is difficult to find. However, a recent survey (Roca, 1986) provides some interesting insights: of the 206 institutions included in the sample, only 51 (24.6%) could be classified as agricultural. Of the 106 responding institutions, only 39 (36.8%) were agricultural.

11. This table provides an indication of the extent of TNC involvement in the seed industry, and by extension, the level of integration with crop inputs supplied by agroindustries:

Industry	Country	Estimated turnover (million US$)
Pioneer Hi-Bred*	USA	520
Royal Shell (oil)	UK, Netherlands	200-300
Sandoz (phamaceuticals)	Switzerland	290
LaFarge Coppee/ORSAN Semences	France	200
Volvo Provendo. (automotive) (Hilleshop/Weibull)	Sweden	170
Pfizer/Dekalb* (pharmaceuticals/seeds)	USA	150
Upjohn/Asgro* (pharmaceuticals/seeds)	USA	140
Ciba Geigy/Funk (chemicals/seeds)	USA	130
Lubrisol/Agrigenetics (chemicals/biotechnology)	USA	110
Cargill (agribusiness)	USA	80-110
Elf Aquitaine/Sanofi (oil/seeds)	France	90
Rhone Poulenc (chemicals)	France	n.a.
Monsanto (chemicals)	USA	n.a.
Occidental Oil (oil)	USA	n.a.
ARCO Seeds (oil/seeds)	USA	n.a.
Continental Grain/Pacific Seeds (agribusiness/seeds)	USA	n.a.

SOURCE: Grooseman (1987).
*Traditional seed company.
n.a. = not available.

12. Basic research results, if not completely withdrawn from the public domain, will at least be delayed until there is a certainty that making them freely available does not diminish the possibilities for their commercial exploitation. The 1981 US Supreme Court decision Diamond vs. Chakrabarty made it possible to patent novel living organisms and opened the way to protect and commercially exploit basic knowledge. To date, not many countries have accepted the possibility of patenting living organisms or seeds (agrochemicals and fertilizers are already included in existing patent laws), but there is an on-going discussion about this topic in the International Union for the Protection of Industrial Property. The consequences of patent laws for seeds could be very far-reaching. Plant breeders' rights legislation does not prevent other breeders from using protected varieties for further breeding purposes. Patent protection by taxing use would even make breeders pay for the use of protected seeds in their research. The consequences of such a situation need not be elaborated (for a further discussion of this topic, see Kloppenburg 1988).

13. In the seed industry, which is increasingly dominated by TNCs, many countries will want to have crop improvement programs capable of supporting the local production of improved seeds to safeguard against oligopolistic behavior, excessive dependence on other countries, and a bias toward the development of improved varieties with undesirable traits, such as excessive dependence on the use of agrochemicals.

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Session IV
Summary

Mobilizing and Sustaining Support for Agricultural Research

Introduction

Several papers introduced the topic of mobilizing and sustaining support, followed by plenary discussion. Starting from the most macro level, two papers dealt with the overall level of support to NARS and ways to increase support from domestic sources. These were followed by concentrated attention to the issue of sustainability of African institutions, the need for coordination of donor input as seen by both a donor representative and a national research leader, improved relations among and between NARS and international centers, and the role and contribution of the private sector.

Plenary Presentations

Global database for NARS

The first plenary presentation by Pardey brought out new information on global trends in human and financial resource commitments to NARS dating back to 1960. It began with a discussion of productivity trends in different regions. With the exception of sub-Saharan Africa, all regions of the world show increases in both land and labor productivity.

Europe, North America, and Australia continue to become more land-intensive in their production while raising labor productivity. Japan is becoming more land-intensive, and while showing only marginal increases from a high output per unit of land, it has raised output per unit of labor significantly. Asia and the Pacific show small increases in labor intensity but still manage through increasing yields to raise output per unit of labor. West Asia, North Africa, and Latin America are raising both land and labor productivity without major changes in their proportion of production factors. The unusual case was Africa, which is using less land per person and showing declining output per unit of labor.

The paper clearly showed the growing share of developing country NARS in the total resources committed to agricultural research. Over the period 1960-1985, developing countries increased their share of scientists from approximately 21% to 45% of the total. This increase in the share of scientists, however, was not matched by their share in total funding, which rose from 24% to just under 35% of the total. During this period, the number of scientists in NARS was growing exponentially while the number of scientists in developed countries was growing linearly. This made it easier to raise financial resources per scientist in the developed countries.

Particular attention was given to trends in research funding on a regional basis. Basing comparisons on purchasing power parity (a measure of what a dollar buys in each region) the developing country NARS are investing more than they traditionally have, but the growth in their spending is nevertheless lagging behind that of developed countries. The use of a purchasing power parity comparison showed that a dollar spent on research in Africa buys less in real research resources than a dollar in other regions of the world. Looking at real expenditures per scientist, developed countries succeeded in raising the mean level of support above the $60,000-80,000 range over the period 1960-1985. The variation about the mean for developing countries increased, and a larger number of systems fell in expenditure classes below the mean. In short, some systems manage to do well, but an increasing number are doing poorly. A regional analysis of these trends again shows that sub-Saharan Africa is faring the worst – raising serious concerns about the productive use of human resources that have been developed.

Determinants of research support

The paper by Elliott and Pardey takes the analysis one step further, and relates the financial trends to structural and institutional considerations in raising the level of support to NARS. The paper analyzed the oft-cited "agricultural research intensity ratio" (the ratio of expenditures on agricultural research in relation to agricultural gross domestic product). While cautioning against comparing a country's ratio against an arbitrary target (the "2% rule") or against countries with different resource endowments, it noted that an improvement over time in a country's ratio is unambiguously an improvement in the level of support. The ratio was broken down into four ratios representing the priority given to research within the agricultural budget, the priority given to agriculture within the government's expenditures, the fiscal capacity (or will) of the government, and the structure of the economy.

By looking at each of the components separately, one could see ways to improve the level of research support in relation to agricultural product. NARS leaders could then look at points of intervention to raise the share of agricultural expenditures going to research: raise the overall expenditure on agriculture or increase the fiscal effort through mechanisms which would tie taxation to research expenditure. This would happen along with structural changes in the economy which would create new taxes for groups that could be considered beneficiaries of the research results. The overall conclusion was that while developing countries recognize the value of research, they are constrained by fiscal weakness and the magnitude of the tasks. Nevertheless, political will could lead to increased research support. For countries at the lower income levels, donor support was required to help them "over the hump" from a situation in which agriculture is the principal source of finance to one in which other sectors contribute to public expenditure in support of agriculture.

Sustainability of African research institutions

Eicher's paper put the issue of sustainability in an African context. Any strategy for sustainable institutions in Africa must be derived from a better understanding of the African context. This is characterized by the small size of African countries and their poverty. In such a context, the primary strategy would have to be intelligent and systematic borrowing.

Eicher reviewed research in the colonial period, and the advantages of a subregional approach. Significant breakthroughs were achieved in export crops such as oil palm and maize by small, well-focused teams. The spillover was large through organized transfers at the subregional level, but also turned out to be much wider. He emphasized the value of certain NARS taking on a technology-generating role, while others become intelligent borrowers (technology adapters). In this perspective, large-scale donor-financed support to NARS may be postponing the need for individual NARS to rationalize research on a regional basis in each of the five major regions. The result is an increasing dependency on donors and international centers, a failure to develop the potential technology generators, and in high-potential countries, inadequate attention to the complementarity between higher education and agricultural research.

Rationalization of donor support

Schurig detailed the donor coordination efforts within the Special Program on African Agricultural Research (SPAAR). Using the donor coordination group for Tanzania as an example, he demonstrated that SPAAR donors have a clear perception of the need for coordinated action, and a willingness to act based on clear national priorities. The group was willing to fund a strategic planning process, and bilaterally support individual components of the plan. In short, money was not the principal bottleneck to improved research support.

Muturi presented the case of Kenya seen by a NARS leader. The need for a clear national strategy "owned" by the country is the basis for coordinated donor support. He confirmed that the aggregate level of support to the NARS was not always the bottleneck, but the support too often reached only small parts of the system, and redirected national resources from the main priorities into peripheral, low-priority research.

NARS linkages

Sène, drawing on the experience of Senegal, widened the discussion to deal with relations between a national agricultural research institute and the international centers. The Senegalese Agricultural Research Institute (ISRA) was the prototype national system created out of semi-autonomous commodity institutes dating from the colonial era. Large-scale donor support, building on the privileged relationships that the original French institutes brought into ISRA, and growing relations with international centers provide the background for the development of a national system. A review of particular relationships demonstrated that national priorities could be maintained if attention was given to building a partnership of equals.

Private-sector research in agriculture

The final plenary presentation dealt with the role of the private sector in Latin America. Trigo put the issue in the context of technical change which has altered the relationship between public and private research institutions. As agricultural development became increasingly science-based, the technologies can increasingly be produced and appropriated by private firms (mechanical and chemical technologies, hybrid seed, and biotechnology).

The growing role of the private sector in agricultural research was discussed in terms of six characteristics and their implications:

- the increasing privatization of knowledge;
- the role of transnational corporations with origins outside of the agricultural sector;
- the need to place agricultural research within a clear science and technology policy;
- the crisis of the public sector in general and the low image of public-sector research at a time when the private sector appears to present an alternative;
- the role and response of IARCs in the face of these changes;
- the potential of the private sector to contribute to the funding and execution of agricultural research.

Group Discussions and Recommendations

Global outlook on the status of NARS

The conclusions that emerged from the database presentation were:

- NARS are making good progress in terms of numbers of agricultural scientists, but not doing as well with increased funding.

- Support levels are still not close to real needs and the balance between personnel and operating expenses is more skewed.

- Some NARS are doing better than others. On a regional basis, the African NARS need the most assistance.

One working group elected to see how the information base which is being developed by ISNAR could be made more useful to NARS, governments, and the international community. The working group encouraged ISNAR to continue the project and proposed to expand the database on NARS indicators to include research outputs and impacts. To accomplish this, NARS should be more actively involved in data collection and analysis. The group urged ISNAR to convene a workshop to develop additional relevant NARS indicators and to standardize methodologies.

Mobilizing domestic support for NARS

The need to develop and nurture domestic political will and commitment to agricultural research was evident to all participants in the workshop. This recognition is reflected in the definition proposed by Eicher of a sustainable NARS: ". . . one in which political support is mobilized to provide adequate domestic financing of all core salaries and operating expenses of national scientists."

One thing that came out clearly in the plenary and working group discussions was that political will and commitment to agricultural research in most NARS is past the awareness stage. As Elliott and Pardey noted in the paper on determinants of support, ". . . the developing countries could be seen in their patterns of support to recognize the value of research but they are constrained by fiscal weaknesses and the magnitude of tasks before them."

The ISNAR database provided conclusive evidence that there is a lot of political commitment to recruit scientists. They have been increasing exponentially in the NARS during the last two decades, but the supporting budgets for maintenance and other operating expenses have not kept pace. However, political commitment to scientific manpower has not been total. From the discussions on human resources, it was evident that the government commitment to numbers has not been translated into better conditions of service for scientists, such as higher salaries, more secure tenure, better recognition, and other perquisites.

It was obvious to the working groups that the domestic effort to obtain higher, more stable, and longer-term support for agricultural research ultimately revolves around the credibility of the NARS to their domestic clients and stakeholders. In discussions, the participants suggested the following mechanisms and strategies to gain stronger domestic support:

- Develop a national agricultural research plan in the context of the national strategies for science and technology and for agricultural development. This will assure political leaders (and external donors as well) that research is in the mainstream of national development efforts.

- Establish mechanisms that will allow systematic dialogue between the research community and development planners and policymakers. This will ensure the relevance of research to development objectives and, conversely, enable research to contribute to the political process of defining national policies and strategies.

- Strengthen overall management to enhance institutional effectiveness and efficiency, in particular research linkages with producers to align research more closely with producer needs and facilitate technology transfer.

- Strengthen public information and communication activities in NARS to heighten the awareness of political leaders, decision makers, and the general public to the contributions of research. This could include ex post and ex ante studies on the rates of return from research.

One working group saw a need for scientists to organize and spearhead a lobby for agricultural research.

Another practical matter which attracted the attention of two working groups was alternative funding mechanisms. The participants exchanged experiences with schemes such as cesses, earmarked taxes from imports and exports, contract research with the private sector, and sales of services. The possibilities for similar mechanisms to augment the regular or core budgets for agricultural research need to be explored further at the individual NARS level.

Rationalizing donor support for NARS

While Eicher injected a note of caution against donor support that creates NARS that are way beyond the capacity of countries to sustain in the long run, there was no doubt that developing country NARS will need continuing support from the international community. Elliott and Pardey contributed the following observation:

"Particularly for countries at the lower income levels, donor support is required to help them over the hump to the point where . . . rising fiscal capacity would allow them to sustain an increased level of support to research from domestic sources." Thus the discussions revolved around how donor support can be made more effective in strengthening NARS.

A common, serious problem is that at times there is a conflict between national interests and donor initiatives. The recent experiences in Kenya and Tanzania are encouraging because the donors are fully aware of the problem and are willing to try innovative approaches to coordinate and integrate their efforts at the national level.

It was recognized that donor support is potentially available in support of clear national strategies. However such support needs to be linked to a demonstrated national commitment to research, along with assurances that it would neither substitute for national effort nor create long-term dependence.

Everyone agreed that the starting point, in Schurig's words, is a "well-drafted, logical, and realistic plan" for national agricultural research to which the donors can tailor their responses to the needs of the country as perceived by the nationals. The burden clearly falls on NARS leadership to articulate the agricultural research needs of the country consistent with national objectives.

At the same time some concern was expressed over precipitate withdrawal of donor support before sufficient domestic support has been mobilized to sustain current efforts. Obviously this must also be seen in the light of donor concern over long-term dependence.

The group discussions did not react directly to Eicher's critique of donor support strategy to agricultural development institutions in Africa. However the two working groups which spent more time discussing African research needs apparently shared many of his premises.

In a general consideration of problems in mobilizing domestic and donor support for African NARS, the working groups highlighted these problem areas:

- unstable political and economic environments;

- comparatively heavier demand upon research because of the complexity of African environments, both physical and social, and the relative lack of relevant information and appropriate technologies;

- early stage of development of African NARS, which is often associated with small size and lack of critical mass, lack of highly trained manpower, more pronounced dependence on expatriates and donor funding, and weak research management.

NARS linkages with other NARS and IARCs

The need and opportunities for more collaboration among NARS themselves received the attention of two working groups. Different modalities of cooperation were discussed, such as networking, common training efforts, cooperative programs, regional centers, exchange of scientific personnel, and exchange of information. What appears to be needed is more documentation and analysis of experiences to guide the NARS, the formalization of cooperation in some instances, and active donor support for NARS-NARS cooperation.

The specific issues of NARS-IARC linkages which were raised included devolution of some functions from IARCs to NARS, the coordination of IARC activities within the country, and the role of the NARS in setting the research cooperation agenda. To address these issues to the satisfaction of NARS, it was considered necessary that NARS increasingly assume the role of an equal partner in these relationships. The IARCs must recognize this, but the NARS must upgrade their capability to perform this role effectively.

Private-sector research in agriculture

The excellent overview by Trigo provided this background to the group discussions:

- The increasing participation of the private sector in agricultural research is a phenomenon that accompanies the modernization process.

- From a positive point of view, the private sector opens up an additional source of resources and brings a certain degree of competition, intensity, purpose, and flexibility into agricultural research which public institutions may not always provide.

- On the other hand, this means that some types of information and technologies are being increasingly withdrawn from the public domain, which limits access by developing countries to knowledge that has previously been free.

- Because of these basic changes, governments need to review existing policies and institutional arrangements.

- NARS must respond positively and adjust accordingly to the emerging trend of private research.

The working groups urged a policy of "openness and caution" in dealing with private-sector involvement in technology generation. The caution is directed at two levels. First, the influence of transnational corporations on the agricultural sector may tend to expand further given the TNCs' existing control over chemicals, pesticides, machinery, and other modern inputs. The control of the TNCs over seeds and the potential new applications of biotechnology could possibly give these foreign institutions an inordinate amount of influence on the growth and direction of a country's agriculture. Of similar concern is the direction and beneficiaries of technological change within the country, since the private sector is not normally expected to look after the needs of the traditional sector. In both cases, the issue is how the country can continue to exercise social control over direction and balance of technological change.

In the new institutional arrangements that need to be evolved to accommodate the increasing participation of the private sector, Trigo proposed that an appropriate division of labor might be for the public-sector institutions to "focus primarily on the generation and transfer of technologies for the small-farm sector and those areas where either the size of the markets or the nature of the technologies offer no R & D cost-recovery possibilities." The private sector on the other hand "should be encouraged to undertake the development of embodied technologies where the proprietary nature permits cost recovery."

This broad division of labor, Trigo stressed, does not imply that the public sector should not continue working on basic or strategic research oriented to create technological potential, or serve as "controls" to assure a minimum level of technological independence at the national level.

Several methods of cooperation with the private sector were discussed, such as joint appointments or secondments, contract research, collaborative research, and sharing experiment stations and laboratories. One working group stressed the principle that whatever institutional arrangements are established, the components of the national research system should operate such that the "competitive structure" in research is preserved.

General observations

In addition to specific observations associated with each of the discrete topics in the agenda, a few general but very pertinent observations emerged in the discussions.

While some global and regional characterizations are meaningful, the uniqueness of the individual NARS needs to be taken into account at every turn. The conclusions emerging in the discussions have to be validated and confirmed at the subregional and national levels.

The stability of national structures is important for achieving impact. Suggestions for improvement are often translated into changes in structure. Structural reorganization presents dangers that are often poorly understood by their advocates. They can disrupt relationships which are beginning to function and actually hold back progress when improved mechanisms and procedures may achieve the same effect.

The question of supply and quality of agricultural scientists was repeatedly brought out in all the sessions of the workshop. The sustainability of NARS as institutions will depend as well on their access to a continuous supply of highly trained nationals for system expansion and replacement. Thus appeals for domestic commitment and donor support for agricultural research should have a manpower training dimension.

In the medium term, the developed country universities and the IARCs may be asked to do more, but ultimately a greater part of the capacity for training should reside in the developing countries themselves. In addition to support for individual national efforts, there is a case for international support for regional academic institutions to meet the needs of the smaller countries.

Finally the NARS must continually evolve with the changing environment. They must recognize the trends in the environment and adapt to them or influence them. The NARS need good management not only to conduct present business more effectively and more efficiently but also to strategically position them for the future. If agricultural researchers are not looking ahead and engaging in the policy dialogue about what the future will be, we will always be acting after the event.

Special Address

Toward a Global Agricultural Research System[1]

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In this chapter I address the task that remains of designing and implementing the global agricultural research system that will need to be in place by, at the very latest, the first decade of the 21st century. I will give particular attention to the special problems of the smaller countries in the emerging global system.

The International Agricultural Research System

It is useful to remind ourselves of what has been accomplished over the last several decades. The architects of the post-World War II set of global institutions included meeting world food needs and reducing rural poverty as essential to their vision of a world community in which all people could be assured of freedom from want and insecurity. They sought to achieve this vision by the creation of a set of global bureaucracies -- the United Nations (UN) specialized agencies. The establishment of the Food and Agriculture Organization of the United Nations (FAO) was the initial institutional response to this concern (Hambridge, 1955).

In spite of limited efforts by the FAO and several regional organizations, it was not until the late 1950s and early 1960s that a combination of

- concern about meeting world food needs,
- experience in advancing technology in food grain production in the tropics,
- a more adequate analysis of the role of advances in agricultural technology in the development process

converged to provide the impetus for a major effort by several bilateral and multilateral assistance agencies and national governments to build the research capacity needed to sustain agricultural production in the poor countries of the tropics.

Organization and impact

One of the most remarkable institutional innovations of the last two decades was the establishment of a new system of international agricultural research institutes (Ruttan and Pray, 1987: Chapter 2, Table 2.1). The organization of these institutes drew on two historical traditions. One was the experience of the great colonial commodity research institutes that played such an important role in increasing the production of a number of tropical export commodities. There is a substantial body of literature in the English language on the development of British Colonial research institutes and botanic gardens (Masefield, 1972; Brockway, 1979). There is no comparable history of French colonial research, but it is clear that research stations developed and maintained by France, during both the colonial and post-colonial period, made important contributions to oil palm, coconut, and a number of other tropical export crops in West Africa (Eicher, 1984). The Dutch made important contributions to the improvement of rice, sugarcane, and a number of other tropical crops in Indonesia and Surinam. One of the greatest tropical research institutes during the colonial period was at Yangambi in the former Belgian Congo. In spite of its rather short colonial history, Germany initiated important research programs in Cameroon, Togo, and former German East Africa (now Tanzania).

The second tradition was the experience of the Rockefeller Foundation in Mexico and the Ford and Rockefeller Foundations in the Philippines (Stakeman et al., 1967). The first four institutes in the system were the products of the joint efforts of the privately endowed Ford and Rockefeller Foundations. The system is now funded by a consortium of bilateral and multilateral assistance agencies and private foundations, and operates under the oversight of the Consultative Group for International Agricultural Research (CGIAR).

An important innovation in the management of the CGIAR system is that each institute is governed by an independent board of directors and operates as an autonomous institution. This structure combines decentralized decision making (with respect to scientific program) with centralized oversight and judgments (with respect to funding, program direction, and system design and strategy).

Relations with developed countries' research institutions

The initial years of the new international institutes were characterized by a tendency to keep relationships at arm's length between the institutes and the developed countries' universities and research institutions. This relationship has changed over time. As the institutes have identified problems in which lack of knowledge in areas such as physiology, pathology, and other fundamental or supporting areas of science has constrained their ability to expand yield frontiers, they have taken steps to institutionalize their relationships with developed countries' research organizations.

Examples include the relationship between the Centre Internacional de Mejoramiento Maiz y Trigo (CIMMYT) and several Canadian institutions for work on triticale. The International Potato Center (CIP) has used contract linkages with institutions of developed countries for work on fundamental problems related to its mission more extensively than any of the other international centers. At the time of the 1977 quinquennial review mission, CIP identified 12 such contracts with developed countries' institutions and seven with those of less-developed countries. In a number of cases, CIP's contracts induced additional effort and expenditure on CIP-related problems by the developed country's contracting institution.

There are clear dangers in the growing relationships among the international centers and the centers of fundamental research in the developed countries. If the less-developed countries are to establish a viable base for self-sustained scientific effort leading to productive growth in agriculture, it is important that they establish a capacity to work on the fundamental problems that are of particular significance in tropical environments.

System impact

Evidence regarding the productivity of the international system is fragmentary and incomplete, yet there is little doubt that the rate of return to the investment in the system has been high – even in comparison with the more productive developed country (DC) national systems (Ruttan, 1982: 242-243). As early as the mid-1970s, evidence developed by Robert Evenson and colleagues at the University of the Philippines and the International Rice Research Institute (IRRI) indicated that the supply of rice in all developing countries was approximately 12% higher than it would have been had the same total of resources been devoted to the production of rice using only the varieties that were available before the mid-1960s (Evenson et al., 1978). More recent studies by Nagy (1984, 1985) suggest that the gains to Pakistan alone from the wheat research conducted by CIMMYT would have been more than enough to cover the cost of the entire CIMMYT wheat program from its inception to 1980. Stated another way, for the same amount of money, Pakistan could have profitably invested in a wheat research program of its own comparable in capacity and cost to the entire CIMMYT program.

In 1983, the CGIAR commissioned an independent study group to assess the productivity and distributional impacts of the technology developed at the CGIAR centers and at collaborating national centers. The study was directed by Jock R. Anderson (1985), a distinguished Australian economist, and the study group's staff was drawn from several social science disciplines from both developed and developing countries. The results of this study are summarized in Ruttan and Pray (1987: Chapter 2).

The international system is particularly important for enhancing and sustaining the productivity of the smaller national agricultural research systems. Personal observation, evidence presented at the Wageningen symposium on research in small countries, and the evidence from the impact study (Anderson, 1985: Chapters 4 and 5) indicate that the international system has provided a mechanism by which many smaller developing countries with only limited national research capacity obtain access to research results from the larger developing countries as well as the international agricultural research centers (IARCs). The infrastructure for this function simply was not in place two decades ago, in spite of efforts by organizations such as the FAO and the Inter-American Institute for Cooperation on Agriculture (IICA).

As the capacities of the less-developed countries' (LDCs) national research systems improve, the relative contributions of the IARC system to the generation of knowledge and technology will decline. One possible outcome of this process is the loss of the institutes' distinct leadership roles. A viable model for the future of the institutes is an expanded role as centers for the conservation and diffusion of genetic resources and of scientific and technical information, relative to their role as producers of new knowledge and new technology. If they are careful to select staff members for their leadership capacities as well as for their scientific and professional competence, they will be able to continue to play a strategic role in establishing research priorities.

There is, however, what might be considered a natural history of research institutes (Ruttan, 1982: 7). A new institute that is able to bring together a team of leading scientists tends to go through a period of high productivity that often lasts a decade or longer. After this initial period of creativity, there is a tendency for the institute to settle down to filling the gaps in the scientific literature and to fine-tuning incremental changes in technology. It is possible that the system of governance adopted – program autonomy at the individual center level combined with centralized oversight – will enable the CGIAR centers to retain and enhance their vitality over a longer time. But the difficulties experienced by the Technical Advisory Committee (TAC) and the CGIAR in attempting to reform management and programs at several "problem" centers do not lead to great optimism about the capacity of the individual centers to avoid cycles of creativity and stagnation.

A second factor that could make an important contribution to future vitality would be the incorporation of stronger LDC representation in both the governance of the system and, at the operational level, in research planning and collaboration. If the international institutes are able to strengthen their capacity to link the national systems to a carefully articulated international system, they will assure their own continued viability. If they become viewed as being competitive with national research systems, they could fade away into mediocrity.

A continuing need for international support

When the system of international centers was being established by the Ford and Rockefeller Foundations in the early and mid-1960s, there was a general perception that over a period of several decades the foundations would withdraw and transfer the management and support of the institutes to the host countries. The two foundations have now withdrawn from anything more than token support of the system, but responsibility for oversight and support has been assumed, as noted earlier, by the CGIAR and its member institutions. Yet one still hears comments from both staff members of the DC donors and the LDC national research system that at some time in the future the responsibility for the system can be transferred to the LDCs or that the major units of the system (excepting the International Board for Plant Genetic Resources) will eventually be phased out.

I find such discussions unrealistic! The system should be viewed as a permanent component of the global agricultural research system. This should not mean that every unit in the present system should be regarded as permanent. It is not difficult to visualize circumstances that would lead to the de-emphasis of some programs and the initiation of new programs, but the international system itself should be regarded as permanent. The funding for the system should become part of the permanent commitment of the more developed countries to the agricultural development of the poorer and smaller countries in the system. In this respect there is a similarity between the national funding of a system of regional research centers in larger countries such as China, Brazil, India, and the United States, even though the individual states or provinces also support state or provincial experiment stations.

An incomplete system

The international system remains incomplete. There is a need to rationalize the managing and overseeing of a number of international agricultural research centers that have grown up outside the CGIAR system (Table 1). I also see the need for greater capacity to conduct research on some of the difficult resource problems that continue to inhibit the development of agriculture in tropical environments. It also seems apparent that the lack of basic scientific knowledge represents a serious constraint to the development of viable and sustainable technologies in many areas of the tropics.

The establishment of the International Fertilizer Development Center at Muscle Shoals, Alabama, in 1974 was an initial step in the development of an international capacity for research on resource development and management problems. The recent

Table 1. Some International Agricultural Research Activities Outside the CGIAR

Center	Primary focus	Location	Year of initial oper.	Budget US$ (mill.)	Budget Year	No. of senior staff	Programs
ICIPE	Insect physiology and ecology	Nairobi, Kenya	1970	4.77	1982	46	Crop borers, livestock ticks, tsetse fly, plant resistance, medical vectors, insect pathology, pest management
AVRD	Tropical vegetables	Shanhua, Taiwan, China	1972	3.60	1983	32	Tomatoes, Chinese cabbage sweet potatoes, soybeans, mung beans
ICLARM	Living aquatic resources	Manila, Philippines	1973	1.70	1983	14	Aquaculture, traditional fisheries, resource development and management, information services
INTSOY	Soybeans	Urbana, Illinois, USA	1973	0.95	1983	8	Soybeans

IFDC	Fertilizer	Muscle Shoals, Alabama, USA	1974	6.70	1982	60	Nitrogen research, nutrient interaction, phosphate research, sulfur research, potassium research, economics research, national programs, technical assistance, training
ICRAF	Agroforestry	Nairobi, Kenya	1978	2.20	1983	18	Agroforestry systems; agroforestry technology, information, training, collaborative research
IIMI	Irrigation management	Kandy, Sri Lanka	1984	5.00	(When opera-tional)	10-12 in HQ, 3-4 per unit	Collaborative research, training, information dissemination
IBSRAM	Soils	Not fixed	1985	4.54	(When opera-tional)	5 - 10	Headquarters, soil management networks
INIBAP	Banana and plantain improvement	Not fixed	1985	1.75	(Ini-tially)	Small	Headquarters regional networks

SOURCE: Personal communication from Consultative Group on International Agricultural Research, World Bank, Washington, DC, 1985.
NOTE: Activities currently using CGIAR meetings or in some other way related to CGIAR activities in 1984 (totaling about $30 million).

establishment by a group of CGIAR donors of an International Irrigation Management Institute (IIMI) in Sri Lanka and an International Board for Soils Research and Management (IBSRAM) in Thailand represents more recent initiatives. The establishment of an International Council for Research on Agro-Forestry (ICRAF) in Nairobi reflects a growing concern about the need for research capacity in the tropics on the development, management, and utilization of fast-growing trees to sustain the demand for biomass for fuel and other uses.

A beginning has been made in providing international support for the development of the capacity to work on some of the problems where lack of basic knowledge acts as a constraint to technology development. Within the CGIAR system, the International Laboratory for Research on Animal Diseases (ILRAD) has been forced to direct much of its research to basic investigations. The International Centre for Insect Physiology and Ecology (ICIPE), initially established in 1970, has gradually evolved into an institution with a very substantial research capacity.

The United Nations Industrial Development Organization (UNIDO) has sponsored exploratory studies leading to the establishment of an International Centre for Genetic Engineering and Biotechnology. It is doubtful, however, that it will devote adequate attention to the work in molecular biology that will be most relevant for animal and plant protection in developing countries. In my judgment, there is also a very strong need for research to overcome the lack of knowledge about problems of fertility maintenance and enhancement of tropical soils. In many parts of Africa this lack puts a serious constraint on the ability to design viable short-rotation systems to replace the more extensive slash-and-burn or other long-rotation systems now in use.

Finally, there are serious deficiencies in the knowledge needed to develop economically viable technologies for the control of the parasitic diseases that inhibit the development of more intensive systems of agricultural production. In many cases, the relationship between disease and development appears to be symbiotic. Intensification of agricultural production enhances the environment for parasitic diseases, and parasitic diseases reduce the capacity of rural people to pursue more intensive systems of cultivation (Desowitz, 1983; Walsh and Warren, 1979).

It is not too difficult to generate agreement, at least in principle, on the need for greater international support for research on problems of resource development and management. But there is considerable skepticism among donor agencies about the need for international support for a series of basic research institutes in the tropics. The argument is frequently made that the basic research can be done in DC institutes, particularly in countries such as France, the United Kingdom, and the Netherlands, that have a tradition of tropical research and are now seeing that capacity erode as support adjusts to the disappearance of colonial responsibilities and to budget xigencies. Part of my answer is that the experience of the present IARCs indicates that intellectual commitment to the solution of even scientific problems is enhanced when the scientists working on a problem are located in the environment in which the problem exists. Basic research capacity in the tropics will also facilitate more effective dialogue with the basic research community in the developed countries.

Considerable thought will also have to be given to the appropriate governance for the emerging system of natural resource and basic science research centers. The present CGIAR system is already approaching severe strains on its financial and managerial capacity. There is a pervasive view among donors to the CGIAR system that it will be extremely difficult to push funding for core or base programs at the CGIAR centers much beyond $200 million (in 1985 US$), yet subsets of the same donors have funded the new centers that have emerged outside the CGIAR system.

It would be a serious mistake if new natural resource and basic science institutes were to continue to emerge on an ad hoc basis. One of the great strengths of the CGIAR system is its planning and supervisory role in welding the set of autonomous institutes into an international research system. The CGIAR and TAC secretariat infrastructure could perform the supervisory functions for a much larger system than at present with only a modest expansion in staff. Nevertheless, donor funding considerations may make it desirable to consider the establishment of a new supervisory body, perhaps a consultative group for natural resource research, to govern the new natural-resource-based institutes. It may also be desirable to establish a separate governance system for any new system of basic research institutes — a consultative group for biological sciences for tropical agriculture. As new internationally supported basic research units are established in the tropics, more attention should be given to the training role, particularly advanced training at the Ph.D. and postdoctoral levels, than was the case when the present international commodity institutes were established.

A global system

Finally, I would argue that an effort should be made to ensure that the international system becomes a truly global system. The new international system has been effective in building communications between LDC national research systems. The linkages of the international centers with DC research institutions are, however, generally filtered through the bilateral development assistance agencies. Direct linkages with the national research systems of the developed countries remain underdeveloped. The linkages between the national research systems of the developed countries are even less developed. It is my impression, for example, that there has not yet emerged any institutional capacity to rationalize or coordinate agricultural research between European Economic Community (EEC) or Organization for Economic Cooperation and Development (OECD) member countries. There is a modest program of information exchange between EEC and OECD countries, but these activities appear to be more symbolic than substantive (FAO, 1984). And we have barely begun to build effective linkages between either the national research systems of the developed countries or the international systems with agricultural research systems of the centrally planned countries.

National Research Systems

By the late 1960s, many of the bilateral and multilateral aid agencies were recognizing serious shortcomings in the results of their efforts to support the development of national agricultural research systems. Most national systems in the less-developed countries were unprepared to effectively absorb large amounts of financial, material, and professional assistance. The capacity for scientific management and entrepreneurship of the newly trained scientific community was often underdeveloped. Many systems were plagued by cyclical sequences of development followed by erosion of capacity as budgetary priorities responded to changes in political regimes (Ardila et al., 1981).

Impatient staff members at aid agencies were often unaware of the history of their own national institutions. They had forgotten that the national agricultural research systems of the United Kingdom, Germany, the United States, and Japan had taken decades, not years, to acquire the research and training capacity required to generate the new knowledge and technology needed to sustain agricultural development (Ruttan, 1982: 66-115). Furthermore, the political support available to many national and international aid agencies was often so fragile that support for institution building was difficult to sustain unless a short-term payoff could be visualized. In addition to a sense of frustration with efforts to strengthen national research systems, there was a growing conviction of urgency about the problem of meeting f[illegible]d requirements in the poor countries. The initial success of IRRI's rice program and CIMMYT's wheat program combined to create a conviction that the international agricultural research institute, which could operate independently of the vagaries of the local political environment and could draw on the global agricultural science community for its staff, represented an effective instrument for the management of research resources and for the generation of new technology.

By the mid-1970s, it had become increasingly clear that the productivity of the international agricultural research system was severely constrained by the limited capacity of many national systems, and that the adaptation and dissemination of the knowledge and technology generated at the international institutes were dependent on the development of effective national systems. It became widely accepted that the ability to screen, borrow, and adapt scientific knowledge and technology requires essentially the same capacity as is required to invent new technology (Evenson, 1977a).

Capacity in the basic and supporting biological sciences is at least as important as capacity in applied science. But the outreach programs of the international institutes, even when working through networks such as the international wheat research network, the inter-Asian corn program, and others, did not have the capacity to take on the role of strengthening national systems.

The bilateral and multilateral assistance agencies had no alternative, therefore, but to place the strengthening of national research systems high on their assistance agendas. Both FAO and the Rockefeller Foundation played imporant entrepreneurial roles in this development. After a series of consultations with the leaders of national research systems, the International Agricultural Development Service (IADS) was established, with initial funding from the Rockefeller Foundation, to provide contract research management and development services to national research systems.

FAO, through its Research Development Center, took steps to strengthen its capacity to support training in the field of research organization and management.

The initiatives of the Rockefeller Foundation and FAO influenced the CGIAR to intensify its own deliberations. In 1977, the CGIAR organized a task force to explore the possibility of establishing an international service for the strengthening of national agricultural research within the CGIAR's systems. These deliberations led to the establishment of the International Service for National Agricultural Research (ISNAR) in 1979. There had been some expectations that, in establishing ISNAR, the CGIAR might absorb IADS, much as it had incorporated IRRI, CIMMYT, the International Institute of Tropical Agriculture (IITA), and the Centre International de Agricultura Tropical (CIAT) under its umbrella in 1971. By 1979, however, the CGIAR had become somewhat sensitive about absorbing activities initiated before the CGIAR/TAC assessment and evaluation process. Some European donors were also sensitive about the fact that staffing patterns at the institutes had not drawn effectively on European professional capacity. FAO, one of the CGIAR's sponsors, expressed strong concern that the new service was infringing on an area of traditional FAO responsibility.

IADS (recently merged into Winrock International) has now acquired substantial experience in managing projects designed to strengthen national agricultural research systems and funded by agencies such as the US Agency for International Development (USAID) and the World Bank. ISNAR has acquired considerable expertise in diagnosing the problems that have inhibited the effectiveness of national research systems and in assisting national agencies in planning for research system reform and development. It is clear, however, that the strengthening of national research systems is only partially, and perhaps only marginally, amenable to the efforts of the assistance agencies. External funding agencies have often inhibited the development of national systems as a result of lack of sensitivity in their assistance efforts to the difficulties faced by a national research system in achieving political and economic, in addition to scientific and technical, viability.

As the efforts by the bilateral and multilateral assistance agencies to strengthen national agricultural research systems got under way, it became apparent that the 1970s were witnessing a remarkable expansion in agricultural research capacity in a number of important developing countries (Ruttan and Pray, 1987: Chapter 1, Table 1.1).

When one examines the details of the individual country, however, it becomes clear that most of this growth has occurred in relatively few countries, such as Brazil, the Philippines, India, China, and Nigeria. In 1980, there were only slightly more agricultural research scientists in all of Latin America and Africa combined than there were in the US federal-state system — and fewer than in the Japanese national-prefectural system. Even in those countries that have made substantial progress, the ratio of research expenditures to the value of production remains low — and it remains lowest for those commodities produced and/or consumed primarily by the poorest farmers and consumers.

During the last several years, I have been involved in a series of studies of agricultural research systems in Asia (Ruttan, 1981; Evenson et al., 1986). The concerns about the development of national agricultural research systems that have emerged out of my own research and experience have been reinforced by the series of very useful reviews conducted by the World Bank (1983), USAID (1983), and UNDP-FAO (1984). Although the literature on the performance of national agricultural research systems is much more adequate for Latin America and Asia, the concerns expressed in this section impinge with particular force on many African agricultural research systems (Eicher, 1984; Lipton, 1985). Let me summarize some of these concerns.

Excessive facilities. Excessive investment in research facilities relative to development of scientific staff — there are too many facilities without programs. Many of the premature facility developments are the direct result of the multilateral and bilateral assistance agency programs that find it easier to invest in facility development than in human capital development or program support. Premature facility investment represents a burden on the research system rather than a source of productivity.

Excessive administration. An excessive administrative burden that stifles both routine investigations and research entrepreneurship — a major challenge to any national research system is how to achieve consistency between the personal and professional objectives of individual researchers, research teams, and research managers, and the social objectives of the research system. In many respects the individual scientist can appropriately be viewed as an independent contractor who makes his or her services available in return for professional and economic incentives. Bureaucratic efforts to achieve consistency between the objectives of the individual and the objectives of the system (or simply fiscal responsibility) are often carried to the point where they become an excessive burden on research productivity.

Poor location. The failure of location decisions for major research facilities, often made with the advice of assistance agency consultants, to give adequate weight to the factors that contribute to a productive research location. These factors include:

- location in a community that includes related educational and professional infrastructure;

- location in an agroclimatic environment that is representative of an important part of the area in which the particular commodity is grown or that is representative of a major resource (soil, water) problem area;

- selection of a site with appropriate resources (soil, water) and infrastructure (electricity, transport, amenities).

Differential between importance of budget and commodity. There is often a lack of congruence between research budgets and the economic importance of major commodities or commodity groupings. If new knowledge and new technology were equally easy (or difficult) to come by in each commodity area, a good rule of thumb would be to allocate research resources roughly in proportion to the value (or value added) of commodity output or resource input. It is easy to think of good reasons for departure from such a rule. In a small research system, critical mass (i.e., scale economies) implies the desirability of focusing resources on commodities that account for a large share of output (such as wheat in northern India) or on a commodity where very large gains can be made in a short time (such as lowland irrigated rice in the 1960s). But extreme lack of congruence often suggests that little careful thought has been given to the allocation of research resources or that particular interest groups have biased research allocation to their own benefit.

Research without scientists. The apparent presumption in some national systems that it is possible to do research in agricultural science without scientists — in too many national research systems, commodity program leaders often have neither the training nor the capacity to direct either scientific research or technology development. Salary structures and noneconomic incentives are frequently so unattractive, relative to other national and international alternatives, that potential leadership is eroded, research programs become routine, and returns to research investment are low.

Cyclical nature of national research systems. The cycles of development and erosion of capacity that have characterized a number of national agricultural research systems – periods of rapid development have often been followed by the erosion or collapse of research capacity when external support has declined. Martin Pineiro, Eduardo Trigo, and their colleagues have documented this pattern most thoroughly in a number of Latin American countries such as Argentina, Peru, and Colombia (Ardila et al., 1981; Pineiro and Trigo, 1983). But such cycles are also familiar to anyone who has followed the progress of agricultural research in developing countries in other areas of the world.

Establishing research priorities. Research priorities may be established with little information and analysis. In research planning that has successfully struggled with the problem of allocating resources for research, it has become increasingly obvious that effective research planning requires close collaboration between natural and social scientists and between agronomists, engineers, and planners. This is because any research resource allocation system, regardless of how intuitive or formal the methodology employed, cannot avoid making judgments about two major questions:

- What are the possibilities of advancing knowledge or technology if resources are allocated to a particular commodity problem or discipline? Such questions can only be answered with any degree of authority by scientists who are on the leading edge of the research discipline or problem being considered. The intuitive judgments of research administrators and planners are rarely adequate to answer such questions.

- What will be the value to society of the new knowledge or the new technology if the research effort is successful? The intuitive insights of research scientists and administrators are no more reliable in answering questions of value than are the intuitive insights of research planners in evaluating scientific or technical potential. Many of the arguments about research resource allocation flounder on the failure of the participants to recognize clearly the distinction between these two questions and the differences in expertise and judgment needed to respond to them (Ruttan, 1982: 262-264).

The perspectives and concerns that I have expressed about agricultural research in LDCs are not the exclusive problems of new and growing research systems. Don Hadwiger (1982) has provided evidence that in the United States the "pork barrel" approach to the location of agricultural research facilities resulted in 44% of all US Department of Agriculture (USDA) research facility construction between 1958 and 1977 occurring in states represented by members of the Subcommittee on Agriculture of the Senate Appropriations Committee. He noted that this practice has forced "the federal Agricultural Research Service to operate a 'traveling circus', opening up new locations in current Senate constituencies, while closing some locations in states whose senators are no longer a member of the subcommittee."

Small Country Agricultural Research Systems

We are confronted with a remarkable paucity of data and analysis on the relationship between scale (or size) and productivity in agricultural research. And what evidence there is, even in the way of casual observation, often lacks precision as to whether the size-output relationship being referred to is with respect to the size of the individual research unit (team, laboratory, department), the individual research institution (center, institute, faculty), or the national or international research system. The views that "small is better" or that "big is better" have often been advanced with considerable heat, but with relatively little precision in concept or definition and with even less empirical evidence. The issues discussed in this section represent an important opportunity for research to bring better theory, method, and data to bear in order to advance our understanding.

Size and productivity in research

What little knowledge we do have suggests that the optimum scale of the research is affected by factors both external and internal to the research process. The optimum level of resources devoted to a commodity research program is positively related to the area planted to a commodity in a particular agroclimatic region (Binswanger, 1978). Therefore, determining the optimum scale of a research unit or program involves balancing the increasing returns associated with the area devoted to the commodity (or problem) on which the research is being conducted against the possible internal diseconomies of scale of the research process or system.

The data that we do have suggest that industrial research and development productivity, measured in terms of patents per engineering or scientific worker, is lower in the large laboratories of the largest firms than in the smaller firms in the same industry (Schmookler, 1966; Kamien and Schwartz, 1975). There is similar evidence for agricultural research (Pound and Waggoner, 1972). There also are a number of case studies that suggest very high rates of return to individual public, philanthropic, and private research units, often with fewer than 20 scientific or technical staff members per unit (Evenson, 1977b; Sehgal, 1977). However, many of these small "free-standing" agricultural research units are engaged primarily in technology screening, adaptation, and transfer activities that depend only minimally on in-house capacity in such supporting areas as physiology, pathology, chemistry, and even modern genetics.

Evenson (1977b) also noted that during the early stages in the development of national research systems, experiment stations tend to be widely diffused, to utilize primarily technical and engineering skills, and to be characterized by a strong commodity orientation. In the Chinese system, for example, decentralization includes not only a provincial research system but also autonomous prefectural and county research institutions that are financed and governed at the local level. Evenson also pointed to a trend toward hierarchical organization and consolidation into a smaller number of larger units at later stages in the development of agricultural research systems. These centralizing trends are apparently motivated in part to take advantage of economies resulting from research activities in the basic and supporting sciences and to use the laboratory, field, communications, and logistical facilities economically.

The urge for consolidation can easily be overdone, however. In the United States, for example, there is now rather strong evidence supporting the value of decentralization, even within individual states. For a given level of expenditure, a state system that includes a strong network of branch stations gets more for its research dollar than a state system that is more concentrated. What decentralization gives up in lower costs seems to be more than compensated for by the relevance of the research and the more rapid diffusion of results. There are, of course, limits to the gains from decentralization. Disagreement about the relative gains from centralization and decentralization, and about the relative emphasis that should be given to basic science, applied science, and technology development, has been the basis for much of the recent argument about the organization and funding of the US federal-state agricultural research system (National Research Council, 1972; Workshop on Critical Issues in American Agricultural Research, 1979).

A *minimum national system*

One of the most difficult issues related to size and productivity in agricultural research is the problem faced by the smaller countries in the development of their agricultural research systems. Most of the smaller countries - those in the population range of 4-10 million - do have the resources, or have access to donors' resources, that would permit them to develop, over a 10- or 20-year period, an agricultural research and training capacity capable of staffing the nation's public- and private-sector agricultural research, education, planning, and service institutions.

The 50 or so smallest low-income countries must, however, think of research systems that will often be little larger than a strong branch station in a country such as the Netherlands or Denmark, or in a state such as Texas or Minnesota.

But how can the government of a small country decide on the appropriate size and organization of its national agricultural research system? For countries like Sierra Leone or Nepal, even the financial and professional agricultural research resources of a small American state or a Japanese prefecture are probably at least a generation in the future. The time required to achieve viable research systems for many of the smaller national systems must realistically be calculated in terms of more than a generation rather than the 5- or 10-year project cycles used by most development assistance agencies.

One major focus of the research effort in these smaller research systems must be the direct support of agricultural production and rural development programs. This means a primary focus on applied research and technology development fields such as agronomy, plant breeding, animal production, crop production, farming systems, and agricultural planning and policy. Trigo and Pineiro (1984) have estimated that a minimum research module for one product requires a team of four researchers trained at the MSc and PhD levels, complemented by eight specialists with graduate-level training, plus a complement of support personnel. They estimate that the total cost of such a program would run in the range of US$ 250,000 (in 1984 dollars) (Table 2). For a small country with six to 10 major commodities and several important agroclimatic regions, this implies a research budget of US$ 5-8 million. When this effort is complemented by the noncommodity-oriented research in areas such as soil and water, pest management, cropping systems, and socioeconomic aspects of agricultural production, marketing, and policy, the implications run into the range of US$ 12-15 million.

The viability of even a small nation's agricultural production also requires capacity for higher education in agriculture, at least through the master's level, to support national programs of technology in transfer, rural development, and regulatory and service activities. When these activities are aggregated it is not difficult to arrive at a minimum level of professional capacity, with training at the MSc and PhD levels, of around 250 and with budget support somewhere in the range of US$ 20-30 million for even the smaller (but not the smallest) countries. For the very smallest countries, even this investment is not feasible in the foreseeable future. Any serious attempt to solve the problem of agricultural research and technology development in the smallest countries must face up to the difficult problem of designing a viable system of regional research collaboration (Wilson, 1984).

Interdependent systems

The idea of reducing or eliminating technological dependency generates strong emotional appeal. Yet even larger countries with advanced agricultural research systems – the United States, the Soviet Union, Japan, India, and Brazil, for example – are not self-sufficient in agricultural science and technology. An effective national agricultural research system must have the capacity to borrow both knowledge and materials from the entire world. The problem of how to link effectively with an increasingly integrated and interdependent global agricultural research system is difficult for the state and provincial research units in the larger national systems. It is

Table 2. Estimated Cost of a Minimum Research Module for One Product (in Thousands of Current US$)

Direct Research Costs (60% of total budget)	306
Personnel	245
Four chief researchers, MSc or PhD, three persons per year in plant breeding, agronomy, and insect pest and disease control and one person–year equivalent in socioeconomics and other specializations, according to requirements (soils, physiology, etc.). Total cost per person per year, US$ 30,000[a]	120
Eight specialists, university graduates. Total cost per person per year, US $12,500	100
Training. Calculated on the basis of 2 x 1 rate of retention; total rotation every 15 years; cost of US$ 100,000 per PhD (MSc 60%). Total annual cost for a permanent team of three PhDs and one MSc (approximately)	25
Services and materials calculated as 12.5% of direct costs	..
Equipment calculated as 7.5% of direct costs	
General Costs and Administration (40% of total budget)	204
Includes direction, support, and services (administration, laboratories, library, communication, field, etc.)	
Personnel	122
calculated as 60% of general and administrative costs	
Services and materials	51
25% of general and administrative costs	
Investments and equipment	31
15% of general and administrative costs	
Total budget	510
Percent summary by broad budgetary items (approximate):	
Personnel	72.5%
Services and materials	17.5%
Equipment	10.0%

SOURCE: Trigo and Pineiro (1984).

NOTE: The estimates were made using the budgetary structure of the international agricultural research centers as a guideline for determining the percent of each expenditure item.

a. US$ 30,000 was used as an average of the case for the different countries of the region. The sum includes salaries plus benefits. A variation of US$ 1,000 above or below this average figure implies an increase or decrease of US$ 4,250 in the total budget.

even more difficult for the national agricultural research systems in the smaller countries.

One approach to this problem has been to attempt to establish cooperative regional research programs - for example, the West Africa Rice Development Association (WARDA) and the international crop research networks that are linked to the international agricultural research institutes. Other regional institutions not directly linked to the international (CGIAR) system include the Centro Agronómico Tropical de Investigación Enseñanza (CATIE), the Caribbean Agricultural Research and Development Institute (CARDI), and the Southeast Asian Fisheries Development Center (SEAFDEC). Networking has become the most recent theme in assistance agency jargon, but it is hard to find many outstanding success stories among these efforts. Program activities and cooperative efforts often appear stronger in the glossy pamphlets issued by the organizations than they do in practice (Venezian, 1984). Experience suggests that such regional programs can succeed only with the commitment of long-term external support and with the participation of the external donors in the governance of such centers. Some of the most effective collaborative regional efforts have been organized around the research programs of the international research centers (Plucknett and Smith, 1984).

The international crop research networks, centered around the international institutes, have not been without problems. When the institutes have had confident and effective leadership, they have often played an exceedingly useful role in creating opportunities for productive professional interaction and collaboration. But the institute research networks tend to be selective. At times they have found it hard to bend institute priorities to meet national priorities. Collaborative efforts tend to involve the strongest institutions and the leading scientists rather than those who have the greatest need.

A richer institutional infrastructure is needed to strengthen and sustain the capacity of the smaller national agricultural research systems. In spite of ideological considerations, many small countries have found it advantageous to encourage the transfer and adaptation of technology by the private-sector genetic supply industry or by the multinational firms engaged in commodity production, processing, and trade (Pray, 1983). Firms engaged in the production of crops grown under plantation systems and independent growers producing under contract arrangements with processors have at times provided their own research and development facilities. In other cases, associations of producers have been willing to tax themselves to support commodity research stations. Such arrangements have often been associated with discredited systems of colonial governance. A strong case can be made for reexamining and strengthening the legal institutions and financial incentives for private-sector research, development, and technology dissemination in the developing countries.

The perspectives outlined in this section are highly tentative. Although they are drawn from considerable experience, they should be treated as hypotheses to be tested by further research rather than as conclusions. Institutions such as IADS, ISNAR, and IICA should devote a reasonable amount of analytical effort to attempts to understand the problem of developing and sustaining effective agricultural research in the smaller national research systems.

Some generalizations

In spite of the limited available knowledge, there are a few generalizations about smaller agricultural research systems that can hardly be avoided. One is that the research investment per acre or per hectare will have to be higher in a small system than in a large system to achieve an equal level of effectiveness. This is because the cost of developing, for example, a new millet variety that will be grown on a million acres is not likely to be substantially greater than one that will be grown on half a million acres.

A second generalization is that the cost of developing productive farming systems for a small country with great agroclimatic variation will be greater than for a small country that is more homogeneous. For example, the cost per hectare of developing an effective agricultural research system for Sri Lanka is likely to be much larger than developing one for Uruguay. The issue of guns versus butter in national budgets is also likely to cut more sharply in a small country than in a large country.

Finally, there is no way that a small country can avoid being dependent on others -- on the international agricultural research system, on the research systems of large countries in the same region, on multinational firms -- for much of its agricultural technology. Furthermore, a small nation with a strong research program but a limited agricultural or industrial base cannot capture as high a proportion of the benefits from its investment in basic research as can a large nation with a diversified economic base. Much of the benefit will spill over to other countries. If it has a weak agricultural research system, it will lack the knowledge needed to capture the benefits of research in other countries or to choose a technological path consistent with its own resource and cultural endowments. Even a strong agricultural research system cannot assure autonomy. But small countries do need to develop sufficient capacity in the agricultural sciences to enable them to draw selectively on an interdependent global agricultural research system. They need to be able to choose what is useful to borrow from other national systems and from the international system.

Toward a Reform of Agricultural Research Support

What can be done to replace the deficiencies that characterize assistance for the support of agricultural research, extension, and rural development programs in poor countries? A solution to the problems of "aid effectiveness" in support of research is particularly important at this time. I anticipate that the next decade will experience a decline in the real flow of aid resources and increasing competition among the several claimants on aid resources.

The basic thrust of the needed reforms is to move away from primary reliance on narrow project approaches. In supporting agricultural research, the project system should be largely replaced by a "formula-funding" or "revenue-sharing" approach (Ruttan, 1984). There have been many criticisms of the project approach followed by the major bilateral and multilateral development assistance agencies. The criticism most frequently heard is that the assistance agencies exert undue influence on the content of the national development programs (Faaland, 1980; Salmon, 1983). This criticism is partly justified. It is not too difficult to identify cases in which close patron-client bonds have been established between particular officers in the aid agencies and the leadership of favored national program agencies. Such relationships have often appeared to give particular national programs a degree of stability and continuity that would be difficult to achieve in the unstable political environments that characterize many developing countries.

In my judgment, cycles of development and erosion are inherent in the traditional project approach. The reason for this inherent contradiction is that external assistance provides an alternative to the development of internal political support. National research system directors have frequently found that the generation of external support requires less intensive entrepreneurial effort than the cultivation of domestic political support. Domestic budget support required by donors is often achieved by creative manipulation of budget categories rather than by increments in real program support – particularly when donor representatives are under pressure from assistance agency management to "move resources." Most existing project systems thus have built-in incentives for national research system leadership to direct entrepreneurial efforts toward the donor community rather than toward the domestic political system.

Any effective alternative should attempt to reverse the perverse incentives that characterize existing development assistance instruments. The system should be reformed to provide incentives for national research system directors to redirect their entrepreneurial efforts toward building domestic political and economic support for agricultural development.

I am increasingly convinced that the long-term viability of agricultural research systems depends on the emergence of organized producer groups that are effective in bringing their interests to bear on legislative and executive budgetary processes. The support of finance and planning ministries for agricultural research is undependable. Their tenure in office is often short. And their support tends to fluctuate with the perceived severity of food crisis and foreign exchange demands.

A formula-funding model

What alternatives to the existing system do I suggest? I do not want to be interpreted as completely negative with respect to traditional development assistance instruments. Project aid is often quite appropriate for physical infrastructure development projects. Program aid can be an effective way to provide macroeconomic assistance for structural adjustment or for sector development in a country with substantial capacity for macroeconomic policy analysis and program management. But neither the traditional program aid nor project aid instruments are fully effective in countries that have little financial or professional capacity for providing support for long-term institution-building efforts. New methods of combining the flexibility of program support, effective technical assistance, and sustained financial support for long-term development efforts must be sought.

One innovation that might be used effectively is for the donor community to move toward an approach in which the amount of external support is linked to growth in domestic support. An example of how such a system might work is presented in Table 3. This implies the development of a "formula" approach in which the size of donor contribution would be tied to the growth of domestic support. The formula should include a factor that adjusts the ratio of ext .nal to domestic support to take into account differences in domestic fiscal capacity. Given the political considerations that

Table 3. Three Funding Models of Program Support and Assistance Level for Agricultural Research (millions of US$)

National fiscal capacity	Low		Medium		High	
	National support	Donor assistance	National support	Donor assistance	National support	Donor assistance
Low (40% assistance)	20	8	50	20	100	40
Medium (20% assistance)	20	4	50	10	100	20
High (10% assistance)	20	2	50	5	100	10

impinge on the allocation of bilateral donor resources, implementation of the formula-funding model is probably unrealistic in the immediate future.

Country-level research support group

A second alternative might take its lead from the experience now accumulated with the CGIAR model and the various donor consortia that have been organized to coordinate assistance to some of the larger aid recipients. This could involve country-level research support groups, chaired by the chairman of the national agricultural research council or the director of agricultural research. The support group will need to have available to it relatively long-term program plans for the development and operation of the national agricultural research system. To produce and continuously update this program, the national research system may require external assistance, but in general the program should be the product of the national agricultural and general science policy system. Its focus, to help protect the program from the vagaries of political change, would be on long-term agricultural research needs and goals and on the incremental steps required for implementation.

It is expected that long-term program development and priority setting would be done through an interactive process with the support group. Once the program has been accepted, donor members of the support group, it is hoped, would collectively agree with the host country to help provide the components essential to the execution of the program as a whole. The host country, in turn, would assume the responsibility for moving its national research program along the agreed-upon development path. Initial commitments might be for three to five years, subject to annual review and the course corrections suggested by the analysis and feedback from actual experience.

Use of an institution such as a support group has the potential of helping the country involved avoid many of the pitfalls of the project mode while retaining several of its desired attributes. Donor identity could be retained by relating grants to components of the agreed-upon overall program. These could even be called projects if, for administrative purposes, it were so desired. The support group, like the CGIAR, would be likely to involve bilateral grants developed in the framework provided by the forum of multiple donors and the host country. The impersonal process of contributing to a common fund is not envisioned. However, this would not preclude "incentive funding" of a formula type. At the same time, the danger that a single donor would dominate the priority-setting process or that essential program components would be ignored would be minimized.

The research support group has several other potential advantages:

1. It could contribute to building a national constituency by focusing from the onset on

this essential ingredient for viability. The donors, for example, might agree to increase their contributions by some fraction of the rise that occurred in the real support provided by the nation involved. Other matching provisions might be agreed upon to provide incentives for nurturing and cultivating national constituencies.

2. It could provide reasonable continuity in support. Commitments should be fairly long term and subject to review and extension well in advance of termination dates to avoid the risk of the excessive program fragmentation that is frequently associated with narrowly defined project funding.

3. It could reduce the administrative and management load on the host country through the planning and review process the RSG would follow.

4. It could place donors in a position of genuinely complementing and supplementing one another and the national program rather than competing for "good investment opportunities."

That such a support mode is often discussed but little used is evidence that implementation is not a simple, trouble-free task. The method has, however, been used successfully in Bangladesh and, somewhat more informally, in several other countries. An important element in its success in Bangladesh was that the support group meetings were chaired by the director of the Bangladesh Agricultural Research Council rather than by a donor representative.

A dialogue on donor assistance to national agricultural research programs was initiated by the World Bank in 1981. The dialogue has been continued by ISNAR in a series of meetings with directors of national agricultural research systems. It is imperative that these dialogues be continued. The issue of reform of agricultural assistance should be recognized as one of the most urgent items on the agenda.

Notes

1. This paper is also published in Ruttan and Pray (1987). A more complete version was published in Research Policy (Ruttan, 1986).

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Concluding Session

Conclusions, Lessons Learned, and Agenda for Action

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We had a series of fine reports this morning. They brought back to us the full scope of our deliberations this week, and reminded us of the complexity of our subject. They facilitate my task this morning.

This Meeting – Our Workshop

My assessment of the meeting is positive. I enjoyed the meeting, found it productive and stimulating, and felt that it was time well spent. This was a workshop in the true sense of the word. We all worked.

Objectives. Have we met our objectives? Have our expectations been fulfilled? I feel the answer is clearly *yes*.

- We examined a broad range of issues facing NARS – issues that determine the future demands for technology and hence the future orientation of research programs.
- We examined the practical implications of global trends and developments for NARS, for their future action agenda, and for their organization and management.
- We developed a range of policy guidelines.
- We developed a set of recommendations for action by NARS and for those of us who work with NARS in pursuit of their objectives.

We set an agenda for action. This is the central outcome.

Agenda. Our agenda was broad and ambitious, yet it was viable and meaningful. It obliged us to look at agricultural research (and the challenges ahead) in a broad context. We spent two days looking at the socioeconomic environment surrounding agricultural research and identified a number of dynamic trends. These are challenges for agricultural research systems, in particular NARS. We spent one day looking at the ecological environment surrounding agricultural research. We identified sustainability as another major challenge and issue. Two days were spent looking at both the institutional environment surrounding NARS (equally dynamic), and implications for NARS of all these trends and developments.

In brief, the agenda allowed us:

- to look at trends and issues which are of concern to both developing countries and the industrialized world;
- to understand the many and complex linkages that exist between the agricultural sectors of the two groups;
- to study the linkages between the agricultural sector in developing countries and other sectors of their economies;
- to look at future technology requirements facing NARS – the challenges ahead;
- to look at the response capacity of NARS to face those challenges;
- to see what is needed to build up that response capacity, i.e., the capacity of NARS to deal effectively with future tasks – this allowed us to identify policy guidelines and action requirements to continue the build-up of NARS capacities;
- to develop an action agenda.

Mix of participants. I felt we had a good mix of participants. It was diverse in terms of:

- regional background (four developing and industrialized country regions);
- tasks and functions (NARS leaders, policymakers, universities, donors, IARCs, development assistance agencies);
- disciplinary mix (perhaps too many economists?);
- representatives of NARS of different sizes and in different stages of institutional development.

Our discussions were fruitful and clearly focused on common issues. Despite this diversity, common issues prevailed over differences. One of the lessons learned is that despite regional and institutional differences, NARS face similar problems. The solutions are similar and the principles are the same. The fine-tuning of solutions is country and situation specific.

Program. The plenary and working group mix was fine. The dynamics of interaction worked well and produced results.

Visualization technique. I applaud DSE for imposing this technique upon us. It served as a useful tool to focus on key issues. My compliments to Dr. Klennert and his five colleagues for the quality of process management.

Conclusions and recommendations. I think we succeeded in dealing with a complex task. We systematically analyzed the challenges ahead and reached conclusions on how to approach them:

- We looked at global trends that will influence future technology requirements in developing countries -- the demand side of NARS.

- We looked at the response capacity of NARS -- the supply side. We focused on their need to change and cope with future challenges.

- We looked at specific action requirements to strengthen NARS -- to upgrade capacity and raise productivity.

- We decided we need to plan. NARS need to determine both the what (their future research strategies) and the how (the further development of the capacity to implement those strategies).

Conclusions, Lessons Learned, and Agenda for Action

The central purpose of this workshop was to look at the future evolution of NARS in the light of changing circumstances. In doing this, we agreed on three broad trends:

- NARS must and will continue to evolve in response to changing circumstances. They have done so in the past and have contributed to technological progress. The graphs presented by Phil Pardey give ample evidence of progress in research productivity.

- They need to understand the dynamics of change and actively manage their future growth and adaptation of capacities in line with changing demands for technological solutions. Only active management of change will enable them to develop those capacities that are needed to cope with future tasks.

- Institutional issues acquire considerable importance in the evolution of NARS.

What are the future tasks and challenges?

Demand side of NARS. Looking at future technology requirements, there are a number of global trends that are relevant to all NARS:

- Technology requirements rise as population and income grow and technology intensity increases. This is a worldwide trend.

- Technology requirements become more complex as the goals of productivity and sustainability are combined.

- The easy solutions have gone. Agricultural production is increasingly moving into more difficult environments. We need a Green Revolution for dryland agriculture, yet yield increases under those conditions are difficult.

- Broadening of the research agenda. Urbanization, the extension of the food chain, and the need for post-harvest technology represent additional challenges. Similarly, employment and equity considerations tend to complicate the research agenda even further.

Supply side of NARS. Looking at research capacities and sources of knowledge and collaboration, we similarly identified a number of trends:

- The emerging global research system has an increasing number of actors, particularly in the private sector. For NARS this means more opportunities for collaboration and division of labor. A key requirement is leadership and management to make good use of those opportunities.

- Sheer growth of NARS. NARS have been growing, as the figures presented showed us, and their capacity has been expanding steadily.

- The changing role of NARS. In the global technology-generation process, NARS are increasingly assuming a leadership role. Within the global research system there is recognition that NARS must lead the process of technology generation if progress is to be made. This, of course, places additional demands on NARS leadership and management.

Our common objective underlying this analysis of demand and supply potentials for future technology is:

- to facilitate the evolution of NARS capacities in the direction needed;

- to increase NARS capacities to deal with future technology requirements;

- to better utilize the potential offered by the evolving global research system;

- to enhance the productivity of NARS as ents of technological change in their respective countries.

The outlook. I have concluded from this meeting that on the whole the outlook is optimistic. Both the figures presented from our database and the comments by Vernon Ruttan substantiate this optimism. Long-term trends clearly show an increase in both NARS size and NARS productivity. With the exception of Africa, all developing regions show substantial technological progress (measured in land and labor productivity). Taken together, these past trends and V rnon Ruttan's comments about the dynamics of the global research system, give an optimistic outlook.

Active management of change by NARS is essential to continue this positive trend in research productivity. NARS must continue to adapt to changing needs and circumstances; more than ever they will need to manage. This implies understanding and analyzing the environment, developing an agenda responsive to real needs, and adapting their own capacities to those evolving needs.

Action requirements to facilitate the evolution of NARS

What is needed to facilitate the evolution of NARS in the direction mentioned? What are the main recommendations?

- The number of issues that were discussed was high. Our working groups were highly productive.

- The number of recommendations made was equally high – too many to mention here.

- All recommendations are relevant; their specific weights vary by country and circumstances.

- Each NARS will have to decide on implementing or merely reinforcing specific recommendations in relation to its situation. Often what is needed is to reinforce certain developments; very little is really new.

Similarly, other actors assembled here (universities, donors, development agencies, IARCs) will wish to consider those recommendations that are appropriate for them and in line with their comparative advantage. One example: cost-benefit analyses and rate-of-return studies to document NARS productivity should be taken on by universities in both industrialized and developing countries. Universities are well qualified to do this. While NARS gradually build up their capacity in this area, they should rely on universities. The important thing is that such studies are done, not by whom, but that they are done.

Let me now mention a few broad areas that stand out. Conceptually they all fall into three broad areas of essential functions that any NARS must perform if it wants to be a productive and sustainable institution.

Research policy. Understanding and managing the policy environment of agricultural research, in particular policy formulation and planning, is a central task for any system.

Structure and organization. Developing an organizational structure that is commensurate with the tasks of research systems is important. In practice this means adjusting structure and procedures to follow the needs of agricultural research. Public-sector bureaucracies often provide an organizational setting that prevents rather than facilitates high productivity.

Management of agricultural research. An important task is linking the management of the research process to produce results, and mobilizing, developing, and managing the resources required to conduct research.

All too often people are overly concerned with inputs and resources. More important than inputs per se is the productivity of the research system – the process of converting inputs (scientific capacity and funds) into research output (new knowledge and technology).

The policy area

A clear conclusion of the workshop is that NARS need to build up their capacity for strategic planning. The rationale is that to manage the future evolution of their research in a sustainable way, NARS need the capacity to plan. This implies:

- the capacity to understand and analyze global, regional, and national trends and developments in their economic, social, political, technological, and institutional environments;

- the capacity to plan the institutional evolution over the long term – responding to needs, opportunities, challenges, and threats;

- the capacity to define, realistically, the scope of research systems (An example is that technology generation versus technology borrowing is an option for small NARS. They need to define their mission in line with their expected resources. Intelligent and systematic borrowing may indeed be a more realistic choice for some of the smaller systems than attempting to build a full-fledged capacity for technology generation for which the available resources are insufficient);

- the capacity to formulate clear research technology policies in line with the needs of both the country and its producers;

- the capacity to relate to both policy-sector and other scientific institutions – particularly potential collaborators in the research process – and the capacity to manage such institutional relations from a position of relative strength;

- the capacity to determine the orientation of research programs, to set priorities, and to allocate scarce resources in a rational way.

This is a big task which requires first-class scientific capacity in both the natural and social sciencies. Here NARS face problems because their social science component is often weak. This can be improved in two ways:

- Use social science capacities that are available elsewhere in the system. The larger NARS may be able to tap university talent.

- Gradually increase social science capacity within research institutions.

The second major task in the policy area that was emphasized is to mobilize national commitment to support agricultural research. The point was often made that both funding level and support stability have important implications for NARS productivity. Generating commitment is feasible – as many NARS have shown us. After all, the long-term growth figures of NARS staffing and expenditures are impressive.

The key requirement is an active dialogue with the policy sector. To manage this dialogue in a meaningful way, NARS need to build up their capacity to generate information that documents the productivity and the relevance of their output, and hopefully high rates of return.

Structure and organization of agricultural research

Our discussions concluded that NARS need an organizational setting:

- that allows them to perform their tasks and deliver the products and services expected of them;

- that facilitates the kind of management required for effective research programs;

- that enables them to attract, retain, motivate, and productively utilize highly qualified scientific staff.

We discussed problems such as the fact that the environment of large public-sector bureaucracies is not normally conducive to productive research. We discussed action requirments; there are too many to list here and they depend on specific circumstances.

We agreed on the main thrust of evolution rather than revolution - gradual change. We emphasized the need for stability of basic structures, even in times of gradual evolution. Chances of success are good, as many NARS have shown us. They have evolved organizational mechanisms that overcome some of the inherent rigidities and have thus created a more favorable setting. We should study and document the success stories, and make the models available for replication and adaptation elsewhere.

Another important concern under this heading of structure and organization relates to linkages. All throughout the week we were reminded of their importance. We came to the following conclusions:

- NARS need to be open and outward looking, and ready to cooperate with other institutions that offer potential. In the future, given the trends we saw, they will need to be even more outward oriented.

- NARS cannot afford to work in isolation. This is particularly true for smaller research systems. They are heavily dependent on technology imports - and need to engage actively in technology borrowing. So far, large NARS are more successful in importing technology components.

Our discussion of linkages focused on four broad groups of institutions that NARS collaborate with:

- their clients - farmers and technology-transfer mechanisms (extension);

- training institutions (universities);

- the scientific community at large, both national and international;

- policymakers.

We concluded that effective linkages with those four groups of institutions are essential. And we recognized that these linkages need to be organized and managed.

Client relations – Linkages with farmers and extension. The importance of this issue was reiterated frequently. To be responsive to client needs, NARS need to improve their downstream linkages.

Linkages with training institutions. The reasons for strong linkages between research and training are many. The need for integration is great and is relevant for both large and small NARS. The effects of successful integration are an increase in the critical mass of scientific staff for research efforts, as well as better and more relevant training. We concluded that solutions are country specific and small NARS should approach this issue on a regional basis.

Linkages with the scientific community (national and international). The rationale is that the growing number of actors in the global research system offer many opportunities for cooperation. Building the capacity to cooperate effectively, however, is difficult and requires sound planning.

We reviewed and discussed a number of modalities:

- Horizontal collaboration (NARS-NARS). Given the growth in NARS capacities, this has a great future. The institutional mechanisms used include networks, joint ventures, regional organizational mechanisms, etc.

- Collaboration with IARCs. Collaborative arrangements with the international centers are a steadily evolving "devolution". There is currently discussion of NARS taking over research functions.

- Private-sector involvement. This is happening more and more in some regions, but there are substantial differences between regions. In our discussions we identified opportunities, challenges, and threats. The key to this solution is the capacity to understand potential, utilize resources effectively, rationalize division of labor, organize joint ventures (where feasible), and develop appropriate mechanisms that fit country needs and circumstances. We agreed on the following points:

  - There is work to be done to gain a better undertanding of the opportunities available.

  - We need to keep this subject under review.

  - It will be on our agenda again in the future.

- Donor collaboration. Our discussion focused on NARS capacity to integrate, coordinate, and utilize the assistance of donors. The basic premise is the need to integrate donor assistance into national programs and plans. The required tools include the availability of strategic long-term plans. Dr. Muturi gave us an example of successful donor coordination around a national plan.

Linkages with the policy sector. This is essential to generate support and mobilize resources, as is a dialogue with policymakers. The capacity to demonstrate the benefits of agricultural research is required. We need information on the contribution of research to the economic growth of a country – quantitative information on the returns to investment in research. This implies a need for social science capacity in NARS.

Management of agricultural research

The key issue is combining enhanced productivity of NARS with long-term sustainability of institutions. The immediate target is twofold:

- raising NARS capacity to develop and implement strong and relevant programs with potential impact;
- raising NARS capacity to mobilize, develop, and effectively utilize the human and financial resources required for these programs.

Human resources. We agreed that a key task is to work jointly with NARS in an effort to raise their capacity to develop, maintain, and effectively utilize critical mass of highly qualified scientific staff. We know both quality and quantity are important. Training acquires special significance in this context. Equally important for the sustainability of NARS is the capacity to retain and motivate staff to higher levels of productivity.

We know that retention and motivation of scientific staff requires specific conditions of service (career structure, compensation schemes, incentives, promotion possibilities, operating funds, etc.). We also know that many of these factors are often not available in public-sector bureaucracies, so there is a need to reinforce on-going efforts towards change and adjustment. This reconfirms the need to institutionalize linkages between research and training; models are available of successful linkages from a number of countries.

Financial resources. Our task is to improve NARS capacity to mobilize and effectively utilize financial resources and ensure a stable flow of funding (with an upward trend). This is essential for both the productivity and sustainability of NARS. There is progress, but not enough. We need to reinforce our efforts to mobilize commitment at the national level. The basis for success is the capacity to demonstrate to policymakers:

- the potential of agricultural research to contribute to economic and social development;

- the technology needs of countries and their producers;

- productivity and present output of research systems – research needs to earn "credit" through relevant products and contributions to agricultural development.

Work is required:

- to enhance NARS capacity to mobilize funds;

- to study and develop alternative mechanisms for funding;

- to enhance the capacity to utilize external (donor) funding, particularly in African NARS.

The resource mix. The balance between human and financial resources is important. We found that in the interest of productivity and sustainability we need carefully balanced growth of both components. We saw that excessive growth in staffing may leave no operating funds. Our data show staff growth has outpaced the growth in funding. The consequences are an unmotivated staff that may migrate and severely reduce the productivity of research systems. We need to continue to reinforce efforts to remove this imbalance and promote balanced growth.

Conclusion

On balance, we have what looks like a shopping list. Yet, I am convinced of the following:

- The list is manageable and well organized. It is broad and specific.

- Action is underway on many of the issues. There is progress.

- Reinforcement of action is needed on some of the issues and a shift in emphasis on others.

We know that the following is also true:

- The broad range of issues identified and recommendations made are constraints to higher productivity and sustainability of NARS.

- They fit into a conceptual framework that we at ISNAR are using to work on these issues in a systematic and rational manner.

- They lend themselves to action. Improvements are gradual.

Action – When and by whom. These recommendations are addressed to all of us at this meeting, not only NARS – although NARS are the key actors. Some recommendations can and should be acted upon at the national level. Others lend themselves to regional and global collaboration. An example for involvement of all three levels (national, regional, and global) is the data base on NARS – the development of indicators. This project requires action and collaboration at all levels. It needs one global catalyst to stimulate and coordinate action by the others.

The purpose is to have a better information base with comparable data on NARS. The kinds of yardsticks developed by this project will assist NARS in both analyzing their own needs and making decisions on future strategies.

The kind of action we agreed upon is a consultation of all actors involved to agree on a common methodology, targets, a rational division of labor, and an action plan. We, at ISNAR, shall take the lead in this.

Another example of action agreed upon is regional collaboration among African NARS in institution-building efforts. The seminar proposed by Dr. Schurig would pick up the recommendations elaborated here in Feldafing and translate them into specific action plans at the subregional level.

The message for ISNAR is this: our program is essentially on track. We have to keep going. We shall step up our efforts in the policy and linkage areas. We shall continue to focus on the long-term productivity of NARS, looking on both sides of the equation: inputs and resources, and output and impact measurement. We shall continue efforts to mobilize national commitment to agricultural research, the point stressed so eloquently by Dr. Amir Muhamed.

A Word of Thanks

The time has come to say a word of thanks to all those who made this meeting a success. Turning first to our hosts: our cordial thanks to Dr. Kruesken and Dr. Klennert of DSE. Your center is great; it provided an excellent environment for a productive meeting full of stimulating discussions. The meeting facilities were most effective and your hospitality most generous. We enjoyed being your guests.

Our appreciation to Dr. Narrain of CTA for supporting this workshop as a cosponsor.

My thanks go to the authors of our 14 papers. Your papers were most stimulating, as our discussions have shown. Cordial thanks to all of you, the participants in the workshop. Your participation in discussions and your readiness to volunteer for many tasks is greatly appreciated.

My compliments to our five moderators: Manfred Häbig, Uwe Krappitz, Adelheid Kückelhaus, Matthias Lanzendörfer, and Thomas Schwederski. Your process management assistance has truly facilitated the discussions. You are shareholders in the success of this event.

A word of thanks to Ms. Warzinek and Ms. Nitsche who looked after us so well all throughout the week.

Last but certainly not least, my compliments to the organizing team: Dr. E. Javier, Dr. K. Klennert, and Prof. Renborg. They engineered the program and merit our applause.

Annex

An Introduction to the Participatory Approach as Practiced during the Workshop

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DSE Participatory Approach: Origin and Characteristics

In the context of the full range of DSE activities, a reorientation of working and communication practices became more and more necessary at the beginning of the 1980s. Inefficient communication was at the core of the difficulties in training courses, workshops, conferences, and staff meetings. The most frequently observed manifestations of the inefficiency are:

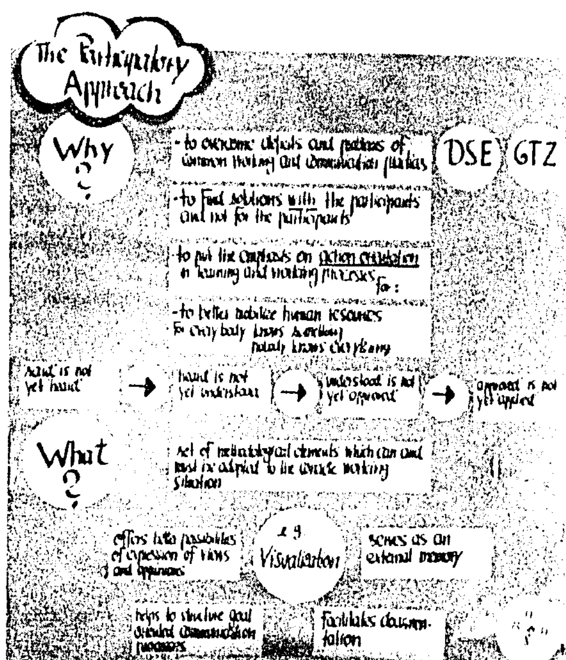
- the domination of one-way communication based primarily on listening and reading, such as paper presentations in conferences and workshops;
- limited possibilities for individuals to express themselves in a group, which leads to:
  - domination of the communication process by opinion leaders;
  - discussion priorities which are not set by the group probably misdirect the discussion, especially on complex topics;
- group members don't absorb much from this communication process, and have little understanding of what has been said in the context of eventually approving and applying it;
- time and human resources are wasted because the communication process is not thoroughly structured.

In reorienting the communication process, better mobilization of human resources was emphasized, whether it was in a staff meeting, a training course, or an international conference. Improving individual participation in all these events became one of the main challenges. The participatory approach was developed at DSE, in particular its Food and Agriculture Development Center (ZEL). This approach cannot be seen as a method with a fixed set of rules, but rather as a set of methodological elements which must be adapted to the characteristics of a specific communication goal. The flexibility inherent in this approach is one of the preconditions necessary to improve participation in communication processes.

Group work, plenary presentations, plenary discussions, role playing, panel discussions, information markets, and visualization are the main components of this set of methodological elements. Each main element consists of subelements – there are different forms of group work, different visualization techniques, etc. In practice, this participatory approach calls for moderators. These trained people must support the communication process in a group by introducing appropriate communication tools at the right moment in order to make the group's work more efficient.

To explain the possible combinations of different elements used in this participatory approach on an abstract level does not make much sense, but this workshop can be used to explain and illustrate this participatory approach. To begin, the participatory approach was introduced to the workshop participants by means of a visual explanation, as shown in Figure 1.

Figure 1. Visualized explanation of the participatory approach



Working Steps

The kind of participatory approach used in the workshop will be illustrated by an example of one presentation and one working group on Session I, Food Surpluses and Their Research Policy Implications.

Visualization of papers

For every paper presented during the workshop, the main issues and the key words were summarized on one or two pinboards. This visualization supported the speaker's presentation, and allowed the listeners to refer to it at any moment during the presentation and the discussion, both advantages which even the use of transparencies cannot offer. In addition to this external memory function, the visualization facilitated the documentation. All pinboards were photographed so that all workshop participants had photos of all pinboards -- and thus all presentations -- at the end of the workshop (see Figure 2).

Working groups

Five working groups were established so that the session's topic and papers could be discussed in more depth. Each working group had a fairly equal representation from the different groups at the workshop (NARS representatives from the different regions, donor representatives, resource persons, sponsors/organizers). Each working group decided the main issues to be discussed in the context of the respective session.

Therefore, the group work started by listing key words, and then clustered and prioritized these key words.

Keyword collection in the working groups

The keyword collection is a kind of brainstorming method with the help of visualization techniques. It starts with a guiding question, usually formulated by the event's steering committee. In the case of Session I the question was:

According to your own opinion and experience . . . differing, agreeing or in addition to what has been thought up in the plenary . . . what are the most threatening and challenging international trends with impact on agriculture in developing countries?

Each participant in the working groups wrote answers to this question on cards with a marker, using only keywords and writing only a single idea on one card.

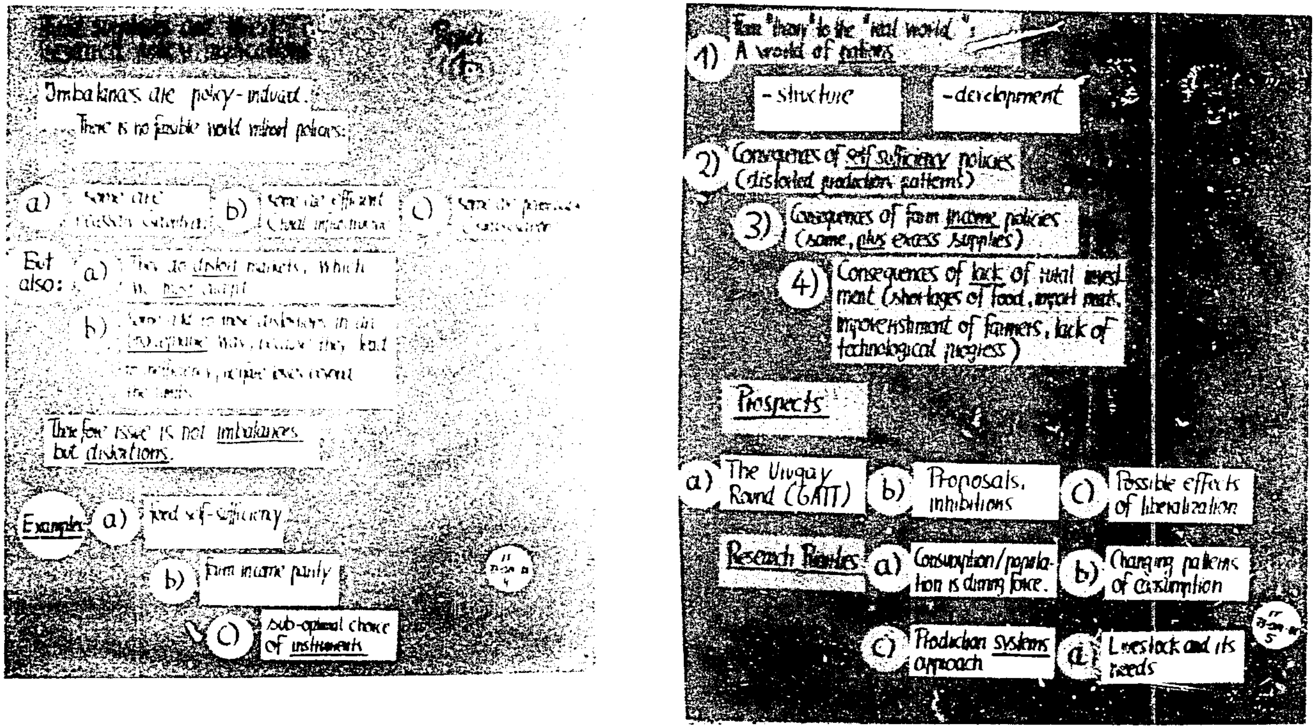


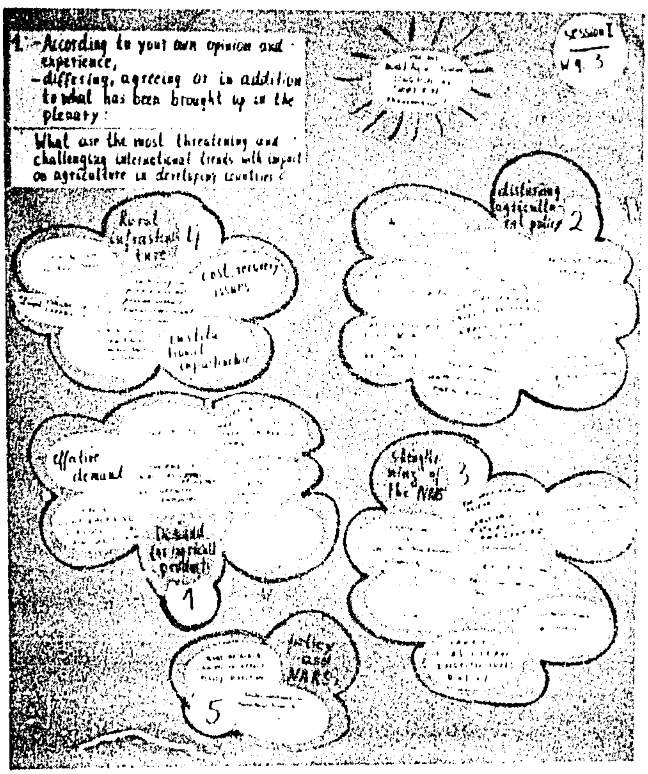
Figure 2. Visualized presentation of the first paper, Global Food Surpluses and Their Agricultural Research Implications, by Prof. W. Tims

After everyone had finished writing, the cards were collected by the moderator, shuffled, and then shown and read to the group. For each card, the group decided where to put it on the pinboards, so that cards dealing with the same problem area were clustered together. After all the cards were on the boards, clusters of different international trends emerged. These clusters were given headings by the group, and dealt with in a priority decided by the group members.

A typical result may be seen from Figure 3. The working group listed these main aspects relating to international trends:

- demand for agricultural products;
- distorting agricultural policy;

Figure 3. Keyword collection (relating to Question 1)



- strengthening of the NARS;

- rural infrastructure;

- policy and NARS.

The idea behind the keyword collection is to give participants a better chance to express their individual ideas and to achieve results as a group which are acceptable to every participant.

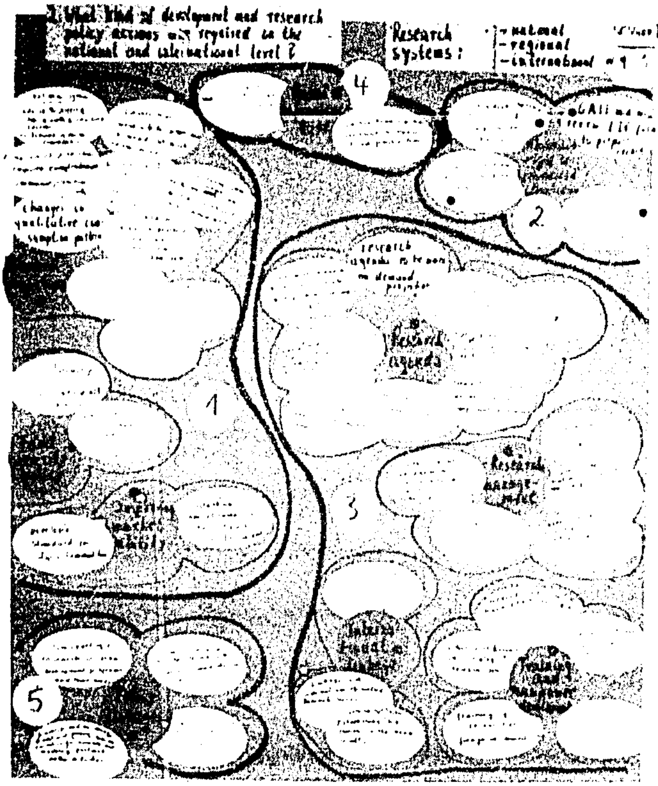
The simultaneous individual reflection brings out more ideas than a verbal discussion ever could, and opens up opportunities for participation, even for those who normally form part of the silent majority. This is particularly advantageous for international meetings where participants have different knowledge and capacity for the language used in the meeting. The visualization also gives more reliability to the individual statements by fixing every card on the pinboard for reference. And if one person feels that his or her idea was neglected during the discussion, it is easy to point out that there is still a card left which has not been considered by the group. In the end, there is a fairly precise picture of the priorities which the group wants to set for a particular topic. By using this procedure to consider complex issues, groups can avoid getting sidetracked into discussions not germane to the topic.

Working with the collected keywords

The ultimate task of the working groups for Session I was to answer the question "What kind of development and research policy actions are required on the national and international level?"

The topics to which the policy actions were supposed to relate had been elaborated by each working group through the keyword collection. The different groups then decided how to continue working using the results of the initial keyword collection. Different options could be noticed. Some groups used simultaneous visualization during more in-depth discussions on aspects of the problems in order to capture their thoughts. Other groups used a matrix which they filled in card by card with their proposals for policy actions and research priorities. And some groups used second or even third keyword collections on policy actions and research priorities for the topics of the different sessions. Figure 4 shows the results of the keyword collection of the same working group and topic as in Figure 3, but this time relating to Question 2.

Figure 4. Keyword collection (relating to Question 2)



Visualized presentation of the working group's results

The visualization of the working group results must be seen as a major tool to ensure that the plenary benefits as much as possible from each group's work. It also stimulates the groups to really concentrate on the main issue for their presentation. Figures 5a and 5b show the visualized results of the working group whose keyword collections were presented in Figures 3 and 4.

The results shown in the figures were achieved in two sessions of one and a half hours each in the afternoon with the whole working group, and one more evening session of the group chairperson, rapporteur, and moderator. Figure 6 illustrates a presentation of visualized working group results by one of the participants.

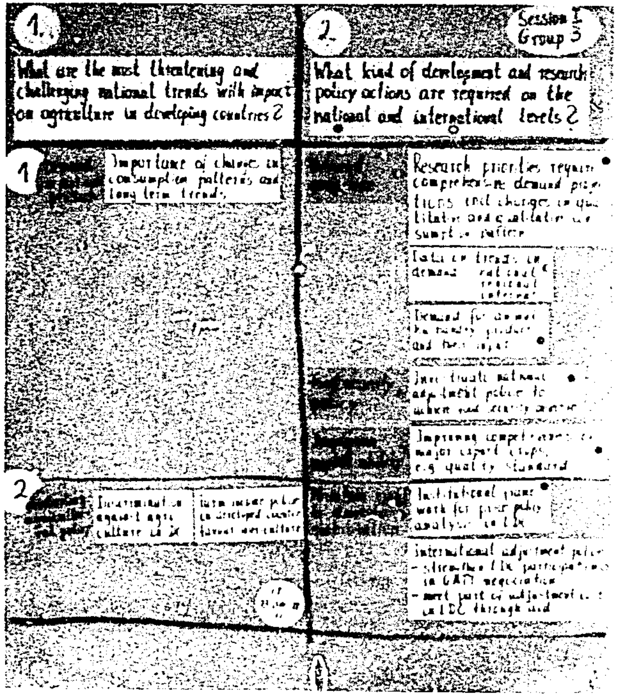


Figure 5a. Visualized presentation of working group results (Part I)

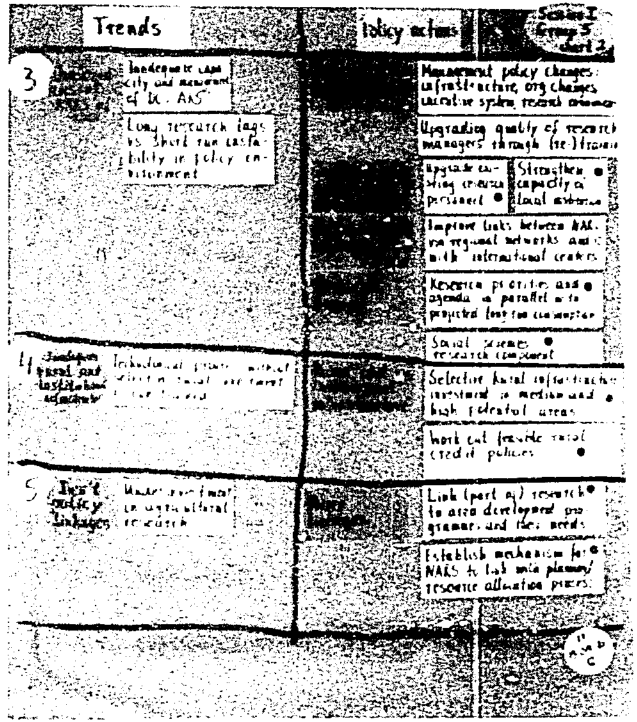
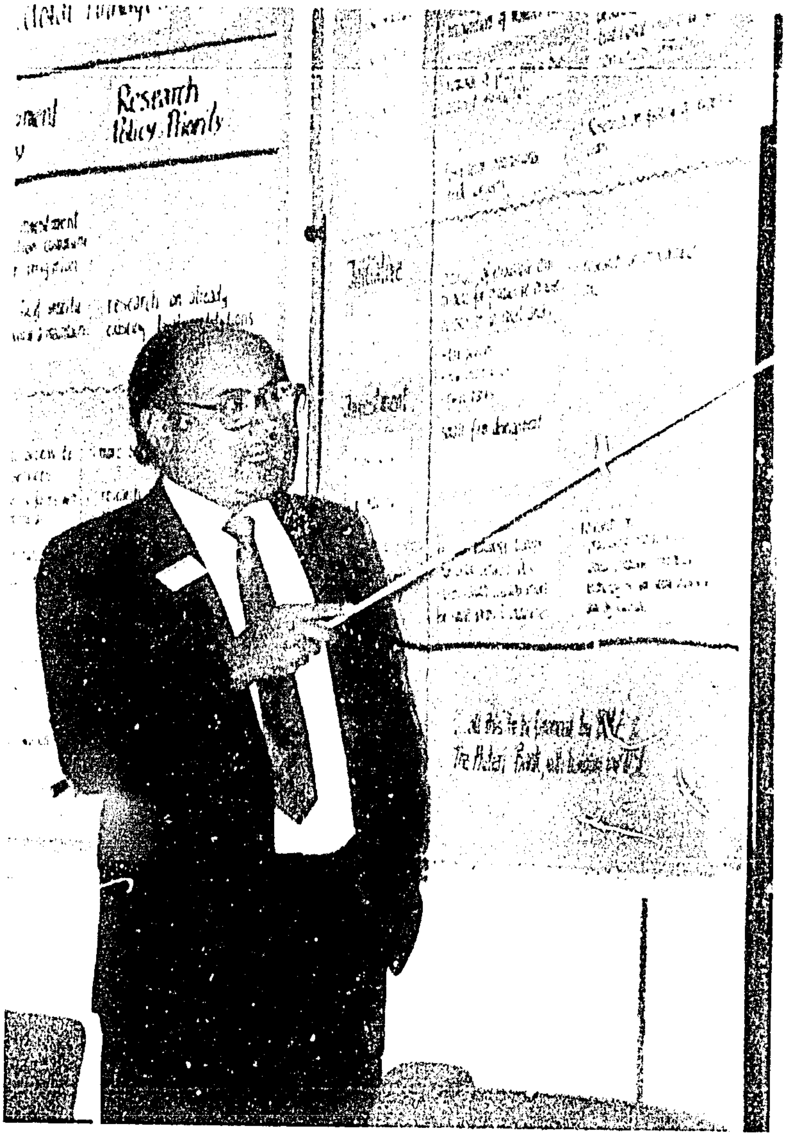


Figure 5b. Visualized presentation of working group results (Part II)

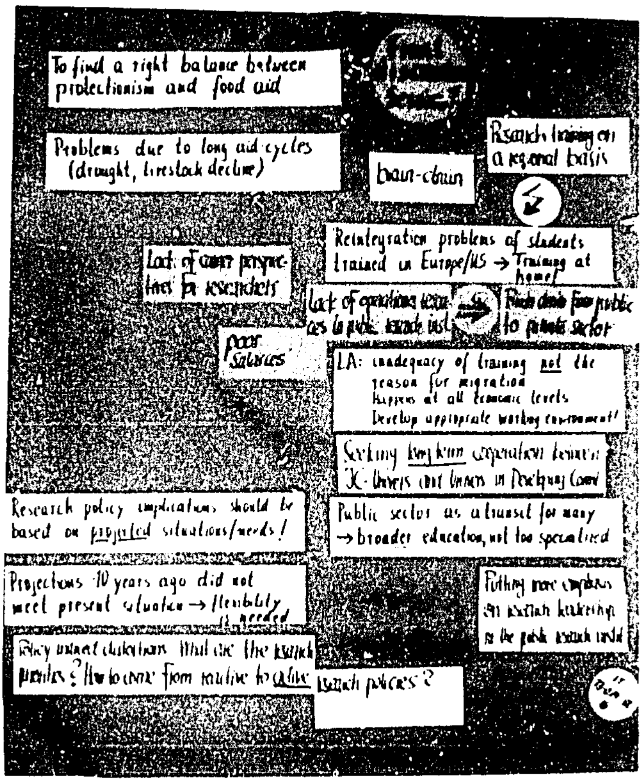
Figure 6. Dr. Gabriel Montes-Llamas, Director-General of ICA, Colombia, presenting working group results



Visualization of plenary discussions

The simultaneous visualization technique was used during the discussions finalizing each session, and also during the discussion following some of the papers. This also made it possible to document participants' contributions during these plenary discussions. Figure 7 shows the results of simultaneous visualization of the final plenary discussion of Session I.

Figure 7. Visualization of the final discussion of Session I



The art of visualization

Participatory group work and presentation of papers or working group results may be supported by using cards of different colors, shapes, and sizes. In that way different kinds of structures may be presented in one diagram illustrating the multidimensional aspects of a system. Figure 8 gives an example of the results of one working group on Session II, "Linking Growth in Agriculture with Growth in Other Sectors of the Economy." Figure 9 shows the fine visualizations on the Giorgoni paper dealing with the same topic.

Figure 8. Visualized presentation of the results of one working group on Session II, "Linking Growth in Agriculture with Growth in Other Sectors of the Economy"

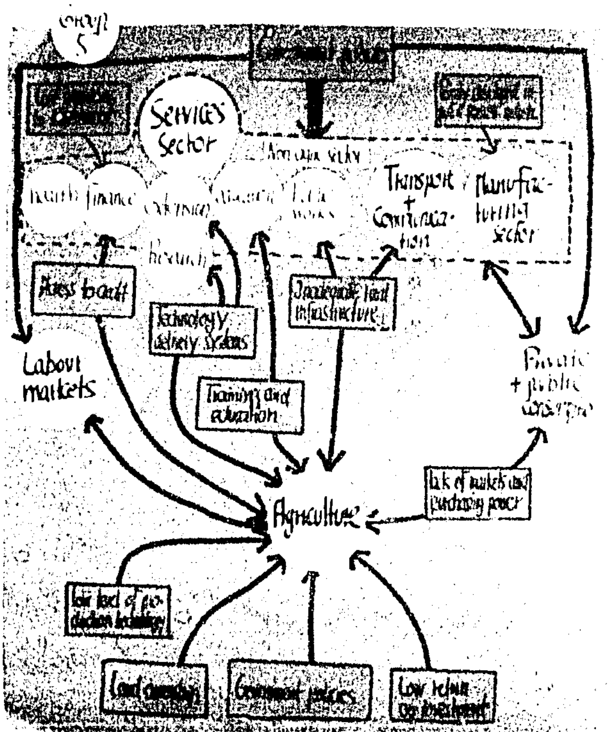
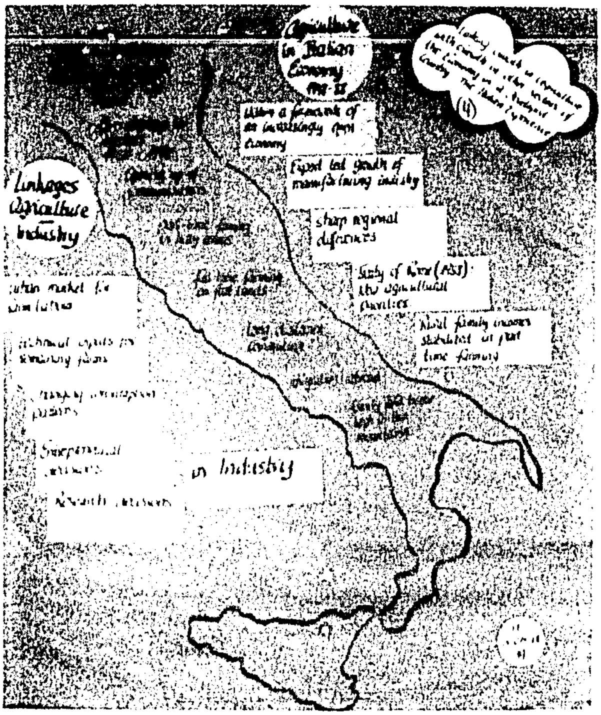


Figure 9. Visualized presentation of paper by Professor M. Gorgoni, presented by Professor U. Renborg, on "Linking Growth in Other Sectors of the Economy in a Developed Country: The Italian Experience"



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