INTERNATIONAL AGRICULTURAL RESEARCH CENTERS:

ACHIEVEMENTS AND POTENTIAL

Part I and II

A Study
Directed by Jock R. Anderson

Draft of August 31, 1985

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FOREWARD

It is appropriate that the CGIAR decided to commission a study of the effects that the centers it supports have had on agricultural research institutions and agricultural production in the Third World.

The external committee appointed to advise on the conduct of the study wishes to raise some issues on its own, and to acknowledge those whose wisdom, foresight, and hard work led to the initiation and successful conclusion of this study.

A word about the role of the advisory committee and the process is in order. Its members were broadly drawn from diverse disciplines and institutions, with varied national backgrounds. The committee functioned as a support group to the director, Professor Jock Anderson, in the design and organization of the study and as a reviewing body at intermediate and final stages. The process worked well -- the advisory committee is pleased with and fully endorses the product. The committee was impressed with the high degree of professionalism and the organizational skills of Dr. Anderson, and has the highest regard for the manner in which he interacted with the committee, assembled his team, and carried out this difficult charge. Dr. Anderson enjoyed especially strong support in executing the project from Dr. Robert Herdt who carried staff responsibility for the study within the CG Secretariat and also interacted most successfully with the committee.

The CGIAR was launched shortly after the first days of the "green revolution" when semi-dwarf wheat and rice varieties, developed by the first

two centers, were spreading rapidly and when the world's attention was focused on the food crisis in Asia. The descendants of these varieties, developed cooperatively with the national programs, remain the largest contribution of the system, and that is large indeed. There are indications that the centers' work on other commodities is also beginning to pay off. Center related maize varieties have spread to over 6 million hectares in developing countries; new bean varieties are spreading, improved potato clones are being used and new cowpeas are being grown by African farmers. The system has made a major contribution through training to increasing the capacity of developing countries to conduct research. These contributions alone demonstrate the enormous utility of a coordinated world system of agricultural research and training.

The wheat and rice breakthroughs were based on a backlog of basic knowledge in the plant sciences that is not so readily applied to dryland crops which are particularly important in parts of Africa, the center of today's food crisis. Wheat and paddy rice are grown on large, rather homogeneous areas while sorghum, millet, cassava, and the various food legumes are dispersed across a wide diversity of ecosystems.

The world's attention is now focused on the profound problem of food in Africa. The causes are manifold: drought, strife, population growth, political imperatives, policy decisions, and world economic conditions all contribute. The CGIAR centers are devoting a substantial part of their resources to these problems: four centers are located in Sub-Saharan Africa, as is the sub-center of another. Their impact has thus far been modest, especially compared with the impact of the semi-dwarf wheat and rice

varieties. This is to be expected in view of the scientific and technical difficulties let alone the other factors responsible for famine.

The committee believes that, in the years ahead, the conditions that led to the initial successes of the CGIAR system will be changing. The backlog of basic scientific knowledge has been exhausted more rapidly than it is being replenished. Many developing countries have organized national research systems (to a considerable extent spurred by the success of the international centers) with the ability to conduct adaptive research. More will do so in the years ahead. This will require bold steps to shift the research focus and the structures of many of the centers from classical adaptive research on specific varieties to the supply of new methods and new breeding materials, many based on the rapidly developing methods of genetic engineering and biotechnology. This involves a changing emphasis from highly applied to more basic research. It also involves enhanced links between the centers and the forefront national laboratories in molecular genetics. These links will be effective only if the centers have staff members trained in these new techniques.

Agricultural science in the 1980s is in a state of rapid transition. Genetic engineering and other tools of biotechnology promise to greatly increase the potential gains from investment in research. Significant advances in molecular genetics, relevant to the work of the centers, have involved discoveries of ways in which the genetic material can be manipulated in animals, plants, and micro-organisms. Since a great deal of the work of the centers concerns the exploitation of germplasm in plant breeding, they must take the earliest possible advantage of the new technologies. This is

especially important since the time required to bring new knowledge into practice is now much shorter, and entirely novel crop characteristics can be created. The CGIAR centers will have to pursue these new avenues of research in addition to or in place of their current activities if they are to expeditiously meet their primary responsibilities to alleviate hunger in the Third World.

It was understandable to address the problem of food production on an emergency basis at a time when millions of people in Asia and elsewhere were faced with almost certain prospects of undernourishment and hunger. These dangers still exist not only for people in large parts of Africa but among the poorer strata of society everywhere. Nevertheless, it is important that problems of food supply are also tackled bearing in mind the longer-term perspective of preserving vital ecological balance and protecting the environment. Short-term gains which jeopardize longer-term goals cannot have a place in an integrated strategy for meeting basic needs worldwide on a sustainable basis.

It has been recognized for decades that there is a need for the development of appropriate technologies that might permit sustainable use of lands subjected to slash-and-burn systems and the other forest removal techniques. Population pressures and numerous other factors have been dramatically increasing the intensity of deterioration of tropical environments. The extreme situation is posed by those millions of small-scale and marginal farmers trapped on degraded lands and lacking new areas or productive lands to which to move.

The international centers and those that sponsor, guide and finance the centers do have a profound interest in the development of systems that can contribute to alleviation of pressures on remaining tropical forests and fragile environments, permitting sustainable agriculture and animal husbandry on cleared lands (thereby reducing further destruction). Consideration must be given to appropriate arrangements for research to help national institutions to develop management methods, technologies, and policies for sustainable agriculture, animal husbandry, plantation forestry or agroforestry, and rehabilitation of degraded tropical areas.

A case can be made that research should not focus exclusively on food crops. The principle of division of labor and mutually beneficial trade applies as much to agriculture as to anything else, and it may make sense for farmers in many poor regions to specialize in commercial crops rather than in food production so as to maximize their incomes as well as the chances of feeding the entire population in the region on an economical basis. The role of international centers, vis-a-vis national centers in research on commercial crops, needs to be worked out in order to meet the needs of poor farmers bearing in mind the crops they are best suited to produce.

Finally, it cannot be overstated that the work of the centers is of benefit not just to the developing countries. It is an aspect of the growing interdependence of all nations that anything which contributes to the well-being of large numbers of people anywhere tends also to benefit the rest of the world. This is perhaps more true of scientific and technological progress than anything else.

Frank Press
Chairman, Advisory Committee

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PREFACE

Background

At its November 1982 meeting the CGIAR endorsed the idea, proposed by the Swedish delegation, that a study be made of the "impact" that the centers had made on agriculture in the Third World. In the early part of 1983, two "brainstorming sessions" were held to which 44 persons from among each of the following groups were invited: CGIAR members, center Directors General, Secretariat staff, TAC and interested observers. They made suggestions and provided cautions about the process that might be followed.

At the May 1983 mid-term meeting the Group gave its approval to the idea of forming a small subcommittee of donors which would select members for a study advisory committee, provide guidance to the Secretariat in formulating the broad outline for the study and provide guidance in identifying a candidate to direct the study. The Group was clear in its determination to have a study conducted by "outsiders," not one carried out by the centers or others inside the CGIAR. The donor subcommittee met twice and submitted a set of names for the Advisory Committee and Study Director to the Group at its November 1983 meeting. At the same meeting the Group approved the tentative propsal for the study, subject to modification by the Advisory Committee and Study Director.

Financing for the study was received from the following members: Sweden, the United States, the United Kingdom, France, the Federal Republic of Germany, Canada, the Netherlands, Australia, the United Nations Development Program and the World Bank. Three members provided services in kind, undertaking particular parts of the study with their own resources.

The Study Director began full time work on the study on February 1, 1984, and continued through January 31, 1985 after which he spent part time on the study through November 1985. Other members of the Study Team were identified and hired as early as possible and the work of locating people to undertake the country case studies and issue papers was immediately started.

The study had one major objective: to determine the impact that the CGIAR centers had made on agriculture in the Third World. Two distinct parts were identified: (a) the contrbution the centers had made to assisting developing countries improve their own agricultural research capabilities, and (b) the contribution the centers had made directly or collaboratively with national programs towards increasing food production.

It was decided to conduct case studies in as many developing countries as practical to ascertain information bearing on the first issue. Those case studies, plus whatever other sources of data or information could be obtained, were to be the basis for judgements on the second issue. It was further decided to conduct a series of studies of particular issues on which the centers might have been expected to make an impact.

The results of field studies started becoming available in August 1984, but the bulk of country studies and issue papers were received between November, 1984 and February, 1985. Some papers were received as late as July 1985. A list of country case studies, issues papers and their authors follows:

The Report

This main report was compiled in the first instance by the Study Team consisting of Robert W. Herdt, Carl E. Pray, Grant M. Scobie and Jock R. Anderson (the later in consultation with Hans E. Jahnke on the African Country case studies). Finalizing the text was very much a team effort but the starting point varied from chapter to chapter. Some chapters represent a team editing or summary of usually much longer reports: chapter 8 mainly from Michael Lipton and Richard Longhurst with new material on North Arcot from V. Rajagopalan and P.K. Aiyasami and on Colombia from Eugenia Muchnik de Rubenstein; chapter 12 from Jack Hawkes; chapter 13 from Paul Teng and David MacKenzie; chapter 14 from Michael Nelson; chapter 15 from Robert Brinkman; chapter 17 from a group of authors at the UK National Institute of Agricultural Engineering coordinated by Robert Bell; and chapter 18 from Jake Halliday. The Summary of the report was prepared by Steve Breth.

The study absorbed generous amounts of secretarial skills. Donna D. Thompson especially and Barbara Thompson and Sue Kaplan served as secretaries to the study. Others who assisted willingly with typing chores included Noemie Del Marr, Janette Abdul-Ghani, Sue Lucas, Leanne Frost and Judy van Baal. Narendra Rustagi served as research assistant and Dorothy Marschak coordinated the editorial tasks in the related study papers. To all those and the many other friends of the study the director wishes to express heartfelt gratitude for jobs well done.

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The Advisory Committee

The Advisory Committee, whose members are listed overleaf, met three times over the course of the study. In January 1984 the Committee first met and agreed to a general plan of work for the study and its broad scope. The second meeting was in October 1984 when the Committee reviewed the progress, some of the early documents, the revised plans for completion and a preliminary report to the meeting of the Consultative Group in November 1984. At its final meeting in July 1985, the Committee reviewed drafts of the main report and its summary, and advised the study director on preparation of the final documents. It also considered the Forward to be prepared by its Chairman, and his presentation to the Group meeting in October 1985.

At its final meeting, the Committee also had the benefit of a commentary prepared by a Panel of independent authorities from the developing countries. This Panel assembled through the good offices of IDRC, consisted of Dr. Farzam Arbab, Dr. Martin Pineiro, Dr. Phillip Chigaru, Mr. S.W. Sadikin, Dr. J.H. Kasembe and Dr. Francis Idachaba. The Committee asked the study director to endeavor to take account of these helpful comments in preparing the final versions of the reports.

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ADVISORY COMMITTEE

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Metric Abbreviation and Units Used

Kt (kiloton)	= 1,000 tons
Mt (megatonne)	= 1 million tons
kg (kilogram)	= 2.2 pounds
ha (hectare)	= 2.47 acres

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Part I INTRODUCTION

Overview

The CGIAR, formed in 1971, grew out of a history of international initiatives for new technologies relevant to developing countries. There had been some early successes with improving rice and wheat productivity that led the donor community to this unique arrangement for multinational assistance to world development. The intellectual predecessors to this movement include a growing appreciation of the importance of agriculture in economic growth, and the successes in various countries, particularly the U.S.A. and W. Europe, of technological progress based on research. Some of these developments are charted in chapter 1. In the train of these multilateral and international initiatives was the significant evolution in the priorities accorded to investment in agricultural research in developing countries. These developments and their current manifestations are taken up in the introductory chapter 3 in Part II.

The second chapter in this Part presents a brief description of the scope of the thirteen international agricultural research centers working under the auspices of the CGIAR. This is intended to complement the considerable volume of material that is readily available from the centers themselves. The work of the centers is exposited with the intention of providing a broad appreciation of the forms and roles of international agricultural research.

The general stance taken in the study is sketched in section 1.5.6. The complexity of the centers obliges a broad approach to an assessment of their impact and the range of issues addressed in this report is a reflection of this obligation.

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1 THE ROLE OF RESEARCH IN DEVELOPMENT

1.1 Introduction

Sustained economic growth from time immemorial has been typified by increased agricultural production and a declining importance of the agricultural sector. Rapid increases in real income per capita in today's more developed economies have occurred contemporaneously with a rise in the importance of the industrial sector. However, in every case, technological change in agriculture has been a mainspring of economic growth. From the introduction of irrigated culture some 8000 years ago, through the use of a wooden plough some 5000 years ago, and through the changing farming practices in Europe in the eighteenth century, to the hybrids, chemical fertilizers and machines of the twentieth century, agricultural innovation has been the mechanism whereby the production of food could be accomplished with a simultaneous release of capital and labor for non-agricultural pursuits. In economies where agricultural output and productivity are growing through investment and technological change, resource transfers from agriculture to build an industrial sector, as envisaged in the growth policies of many nations can, in fact, become a reality.

1.1.1 Role of the agricultural sector

One interpretation of the history of recent decades is that, until the 1960s, industrialization formed the cornerstone of economic development policy in much of the developing world where agricultural progress was often tardy and agriculture was often accorded low priority. Rich countries were seen to have generated an increasing proportion of their economic activity in the industrial sector, with a simultaneous decline in the importance of their

agriculture. Many nations embarked on a deliberate policy of industrialization. In both market oriented and centrally planned economies, heavy infusions of capital were made in the industrial sector. As agriculture was inevitably the predominant sector of the economy, it became obligatory that resources be transferred from agriculture - in fact, the agricultural sector was often viewed as a reservoir of resources from which could be extracted the flows of labor, capital and foodstuffs needed to sustain non-farm economic growth.

Many and varied policy instruments have been employed in pursuit of this transfer. Taxes on agricultural exports, land taxes, cheap food policies, multiple exchange rates and protective industrial tariffs are some of the devices used to capture the surplus of agriculture and to use it as a stimulus to industrial growth.

In large measure this strategy failed. It did not induce broadly based economic growth. Instead, a small, highly capital intensive industrial sector emerged, depending for its existence on direct and indirect subsidies and imported technology, and employing little of the expanding labor force. The additional income streams were largely captured by urban elites (including public servants) whose expenditure patterns did little to stimulate demand-induced linkages to the remainder of the economy. Agricultural productivity tended to stagnate, lending credence to the view that the sector was tradition-bound and unresponsive to prices. Its poor performance reinforced the zeal with which industrial development was pursued.

Since the mid 1960s, several countries, including Brazil, India, the Philippines, China, and Thailand, have radically changed their policies toward

agriculture to enable it to play a leading role in development. These countries have balanced policies based on public investments in irrigation and technological change that permit farmers to produce at lower unit costs so that food prices have been held down. Yet, with real costs declining, incentives have been great enough to drive agricultural growth at a faster rate than demand, notwithstanding declines in product prices.

In the absence of technological change, discrimination against the agricultural sector led to stagnation of food production and increasing food prices, the latter driven by population growth rates of three percent and greater. Appropriate investment in infrastructures and human capital has led to technological change that in turn has provided one means of escaping this trap.

1.1.2 Agricultural linkages in a developing economy

Policies that have discriminated against agriculture are now seen to be at the heart of many of the economic crises facing poor countries, leading to slow growth in non-farm employment, compounded by migration to urban areas. At the same time the agricultural sector lacks investment, has stagnant productivity, and a weak system of research and extension. The increased and changing demand for food from urban areas combined with slow growth in domestic output has increased the demand for food imports and subsidies. These place added demands on scarce supplies of foreign exchange and on government budgets, adding further to the disequilibria in both the internal and external accounts. Thus, the ramifications of poor agricultural performance become widespread, serious, and self-reinforcing.

The converse holds where a productive and growing agriculture has favorable effects through the linkages with the rest of the economy. When agricultural growth is based simply on using greater quantities of traditional inputs (land and labor) little surplus is generated to improve incomes of rural people or to be transferred to the non-farm sector. Similarly, little surplus is generated by reorganizing existing resources within farms or communities. Only if the constraints to growth are relieved by new factors of higher inherent productivity can agriculture become a major source of growth in a modernizing economy.

A growing agriculture provides the food necessary to support higher employment in the non-farm sector. Furthermore, it provides additional rural employment directly by expanding output. Even more important, however, is the indirect employment effect of the consumption expenditures arising from new income streams. Much of that expenditure is directed toward labor-intensive, local goods and services. The increased employment of low-income laborers raises the demand for food, as they spend a large share of additional earnings on food. A self-sustaining cycle of economic growth becomes possible. The crucial element, however, is technological change which releases agriculture from its existing constraints and generates new income streams.

In such a process, the contribution of land and physical labor will decline in importance. Investments to enhance the quality of physical and human capital, together with technological change, become key elements in determining the rate and path of agricultural growth. Nations face complex and difficult choices on the thorny path of the development process. Increasingly, they have seen "top-down" "packaged" methods fail, and many are tending towards more broadly-based participatory approaches to involve more,

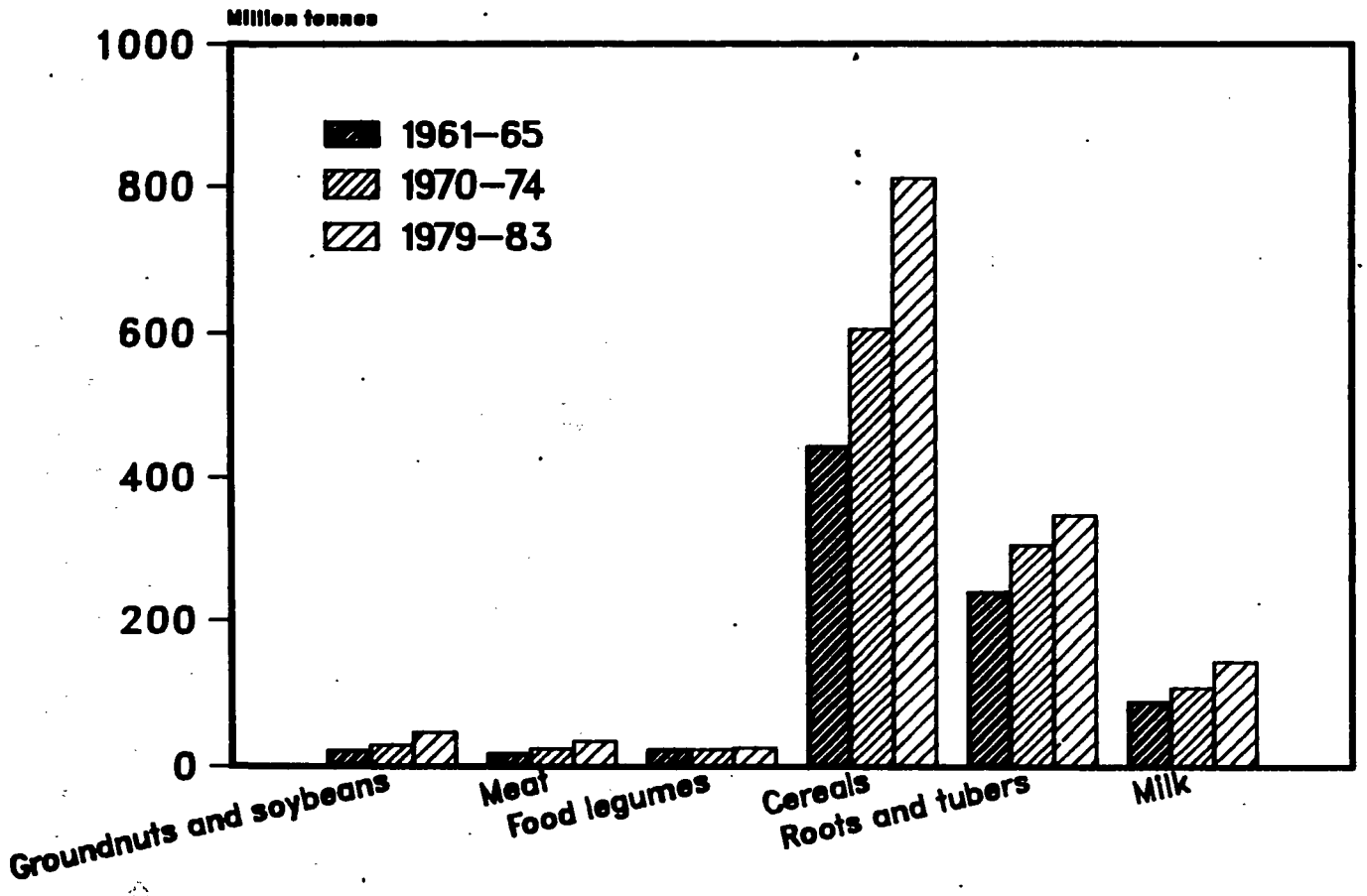
especially the less well off, of their people in the process. International assistance too has often been "top-down", and it is in this changing and difficult environment that the international agricultural research centers must seek to make their contribution to the development process.

1.1.3 Food production

Over the past two decades, production of cereals, oilseeds and meat have increased at over three percent a year in the developing countries, output of milk has increased at over two percent a year, output of roots and tubers has increased at about two percent, and output of food legumes was nearly stagnant (Figure 1.1). Cereals make the largest contribution to food energy and protein, and their growth has been rapid enough to keep food production increasing more rapidly than population in most developing countries. Root and tuber production in the developing countries is estimated (probably conservatively) to be around 350 Mt while cereal production is 810 Mt (for 1983). Meat, oilseeds and food legumes all contribute less than 50 Mt per year, but make a more than proportionate contribution to diet because of their high protein and oil content. Milk, also high in nutrients, provides nearly 150 Mt to food per year.

This record of production of major food crops enabled the developing countries to keep narrowly ahead of population growth so that, in global terms, per capita production increased slightly. With generally declining population growth rates, and increasing attention to agriculture, there are good prospects that food production will continue to exceed population growth in developing countries as a whole.

Figure 1.1
Average annual food production in all developing countries, 1961 TO 1983.



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This general picture hides a good deal of regional heterogeneity that is illustrated in Table 1.1. Between 1961-65 and 1979-83 cereal production increased at between 1.5 and 4.6 percent annually across the major developing regions, with the slowest rate in Africa and the fastest in China. Root and tuber production increased at between 1.0 and 5.7 percent annually, with the slowest growth rate in Latin American and the fastest in India. The other major commodities have an equally mixed picture but the African record in food legumes (2.7 percent annually) is notable.

The six geographic areas for which data are shown in Table 1.1 are roughly comparable in the area devoted to cereals, each having from 50 to 100 million ha. Yields range widely around the recent average of 1.9 t/ha, however, from a low of 0.85 t/ha in Africa to a high of 3.2 t/ha in China. In most cases, the regions that had rapid growth of output did so mainly because of increases in yields.

Even more striking than the rise in production is the rise in consumption and the concomitant increase in food imports. Developing countries, especially those with rapidly growing populations, continue to become increasingly dependent on imported food. The goal of self-sufficiency in food so widely promulgated in the 1970s will prove increasingly elusive for many countries. In fact, there has been an extraordinary growth in food exports from industrial to developing nations. Countries with rapid growth in urban populations fueled by migration from stagnant agriculture have had the most marked rise in imports. Inevitably, food imports by much of the developing world must continue to rise over the foreseeable future. Scarcity of foreign exchange to finance these imports means that much of the developing world will continue to face obligations to increase food production.

Table 1.1 Area, yield and annual production growth rate of major foods in principal regions of the developing world, 1961-65 to 1979-83.

	Area (million ha)		Yield (t/ha)		Growth rate of production
	1961-65	1979-85	1961-65	1979-83	1961-65 to 1979-83
			Cereals		
Africa	48.2	57.1	0.77	0.35	1.5
China	90.4	92.8	1.48	3.24	4.6
India	95.4	104.1	0.94	1.38	2.8
Other developing Asia	50.2	62.4	1.50	2.21	3.4
Latin America	39.9	51.2	1.33	1.88	3.3
Middle East/North Africa	40.8	47.3	1.04	1.35	2.3
All developing countries	365.1	417.5	1.22	1.94	3.4
			Roots and tubers		
Africa	8.9	12.2	6.1	6.8	2.3
China	11.8	10.2	9.1	14.1	1.6
India	0.8	1.3	7.8	12.9	5.7
Other developing Asia	3.1	3.9	7.6	10.7	3.1
Latin America	3.6	4.3	10.3	10.3	1.0
Middle East/North Africa	0.4	0.6	9.4	13.4	5.0
All developing countries	29.5	33.8	8.2	10.3	2.0
			Food legumes[a]		
Africa	6.1	9.8	0.4	0.4	2.7
China	16.0	11.4	0.8	1.1	0
India	19.4	20.6	0.5	0.5	0.4
Other developing Asia	2.3	2.7	0.2	0.4	0.6
Latin America	6.2	8.4	0.6	1.0	1.4
Middle East/North Africa	1.3	1.8	1.0	1.0	2.2
All developing countries	41.5	45.8	0.6	0.6	0.4

a/ Total of dry beans, broad beans, chickpeas, cowpeas, pigeonpeas, lentils

Source: FAO data base

Furthermore, rising incomes are continuously shifting the pattern of demand toward more livestock products so that both the level and mix of output must respond. Increased demand for livestock products adds to the increases in food and feed imports. These issues related to international trade are taken up in more detail in section 1.4.

1.1.4 The role of research

Agricultural innovation, through a process of trial and error by producers, has proceeded since the very inception of attempts at deliberate livestock and crop production. What is now thought of as the modernization of agriculture is little more than a century old, and the most rapid gains have been in the past five decades. During this time grain yields in industrial market economies have more than trebled. However, although cereal yields in 1934-38 were identical in the industrial and developing countries (at about 1.1 t/ha), yields today in the industrial market economies are about 1.5 t/ha, are 1.9 t/ha in all developing countries while in the industrial countries they stand at 2.6 t/ha. The current patterns of food trade are in part a consequence of the more rapid improvements in the efficiency of basic food production that have characterized the agricultural sectors of industrial countries.

While this striking difference in agricultural productivity is due to the complex interaction of many political, economic and ecological elements, it is clear that a significant part can be attributed to investment in human capital, especially in research. Gains in productivity are not a happenstance event, but reflect, in large part the conscious decision to generate technological change through investment in research. The capacity to develop technology that is consistent with the economic and social circumstances of a

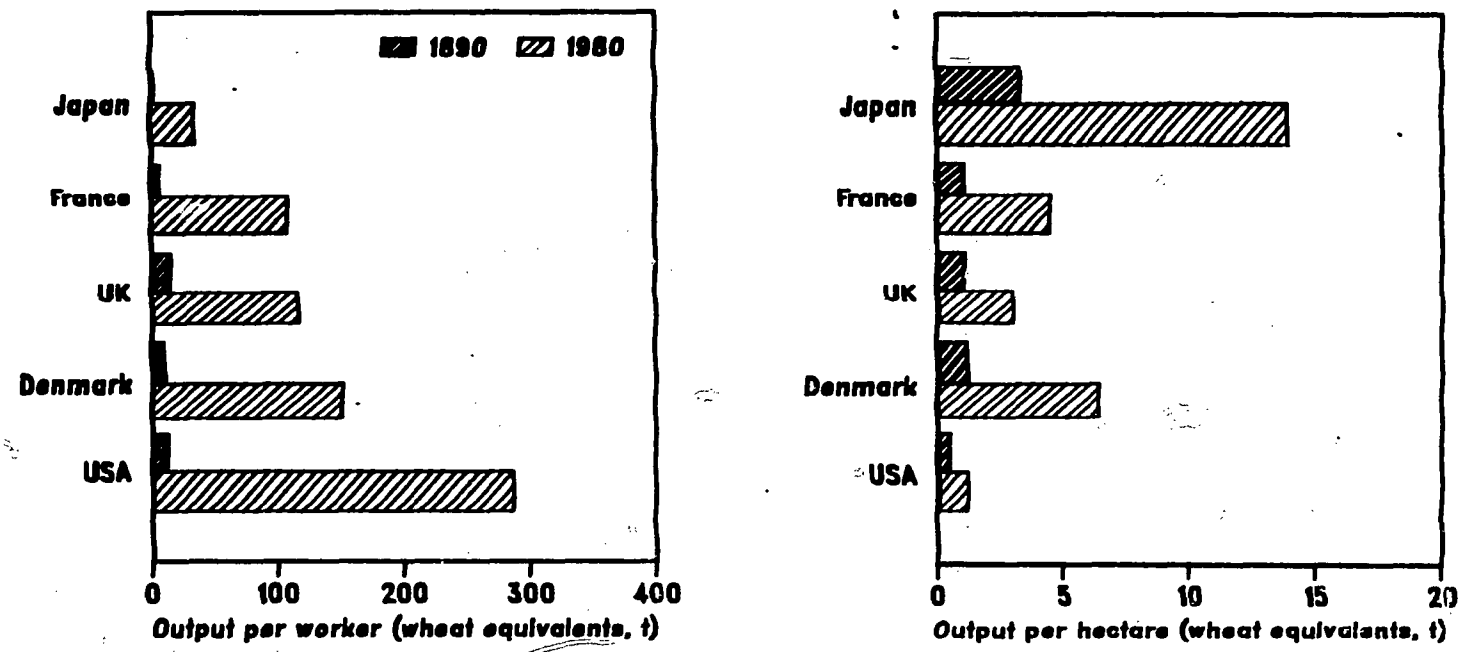
country is a major factor explaining the wide, and widening, differences in agricultural productivity between regions and among nations. Other factors include the on-going and important contributions of innovative farmers and other non-research pioneers of improved technology.

Gains in productivity are, in some minds, synonymous with increased yields per hectare but, to a farmer, reduction in the use of an input with no sacrifice in output is a gain in productivity. Productivity also increases when a reduction in the use of one input is accompanied by an increase in the use of some other in such a way that the cost per unit of output falls. This has been the basis of the productivity gains of the United States, Japan and W. Europe over the past century. They had quite different patterns of productivity gains, however, as is illustrated by the data on output per hectare and output per worker presented in Figure 1.2.

The United States experienced rapid gains in output per worker. Between 1880 and 1980, output per worker increased by a factor of over twenty. Over the same period output per worker in Japan increased by a factor of 15, but it remained, in 1980, at just twice the 1880 level of the US. On the other hand, output per hectare increased nearly 14 t/ha of wheat equivalents in Japan while increasing to only around 1 t/ha in the United States during the same period. Patterns were intermediate in Denmark, France and the United Kingdom. All these countries have had varying but substantial productivity gains in their agricultural sectors, but with considerably different patterns of growth in output per hectare and output per worker.

The initial work of the CGIAR centers and their partners produced technologies that raised yield per hectare in a limited range of environments

Figure 1.2
Productivity per worker and per hectare in five industrial countries, 1890 and 1980 (Hayami and Ruttan, 1985)



where land was the relatively scarce factor. Yield per hectare became, and remains, a quick and easy index of agricultural progress, but there are serious limitations to its use. Land is not the critical limiting resource all areas. In much of the developing world, technologies that save land are not necessarily the most appropriate. There are wide differences among countries, both within a crop and between crops; what was relevant in one place or at one time is not necessarily relevant for other times and circumstances. It would be fallacious to judge the activities of the centers and their partners only according to this criterion. Increases in yield per hectare in themselves are much less crucial for extensive livestock production, for shifting agriculture, for rice in rainfed areas of Latin America, cassava in much of Africa, and potato production in the Andes. Increases in total factor productivity and, in particular, labor productivity are in such cases more relevant indicators of successful technological change. This issues is returned to in section 1.3.2.

The products of research may, furthermore, be relevant for improving yield stability and for allowing more intensive production by shortening the growing season. They may also help to extend the domain of the crop to areas previously unsuited because of diseases or growing conditions. In such cases, yield per hectare will not necessarily rise, despite the successful generation and diffusion of new technology.

These conceptual points are intended to emphasize the difference between productivity gains and yield (per hectare) gains. Although yield is reported extensively herein as an index of productivity, it is an imperfect one. It is used simply because of the unavailability of data necessary for constructing more comprehensive indices. One early observation in this study was the

extreme scarcity of alternative measures of partial productivity in both national statistical reports and in reporting of research results of the international centers.

1.2 The Nature of Research

1.2.1 Lags

Expenditure for agricultural research is a form of investment because real resources must be diverted from other forms of investment or from current consumption and the payoff of this investment is not realized for a considerable period of time after the investment is made.

There are two widely recognized lags involved. In the first place, time is required for the research itself. The length of the research lag will reflect the difficulty of the research challenge, the stock of knowledge available at the start of the work, the amount of resources devoted to the research in both human capital and physical facilities, the amount of research being undertaken in related fields, and the time required for the biological processes to occur not to mention an element of serendipity. Once research findings are available, their payoff only comes after their incorporation into production systems. This second adoption lag will reflect the nature of the innovation and the goodness of its fit to farmers' circumstances, the resources devoted to its promotion, the strength of the inherent demand for it, and the human and other capital levels of the potential users. Any new technology must be tried and evaluated, and the process of acquiring information about it may be costly and time consuming.

It might also be observed that there are two further antecedent lags that should be considered. First is the lag between the existence of an agricultural problem (production, consumption, institutional, etc.) and the recognition of the problem by the agricultural establishment. Second is the lag between the recognition of the existence of the problem and the commitment of resources to investment in agricultural research to find a solution.

Studies in industrial countries have shown that the full impact of successful research typically comes some 8-10 years after its initiation. For livestock production it can be 13-15 years before the full effect of successful research occurs.

These long lags imply the need for sustained research funding over lengthy periods. They also imply that a current increase or reduction in the level of investment will have little or no immediate impact. This sometimes creates an impression that research funding can be cut, at least temporarily, with no real consequences. The argument is sometimes bolstered by reference to an existing stock of unused technologies that await only sufficient promotion to encourage their adoption.

1.2.2 Risks

As with all forms of investment, the fact that the returns to current expenditures accrue some time in the future tends to make research an uncertain venture. It is impossible to foresee with certainty what those future returns will be, or even to be sure that they will eventuate. The inherent riskiness also means that some projects will appear as failures or, at best, partial successes, while others, with equal prior prospects, will generate even greater than expected benefits.

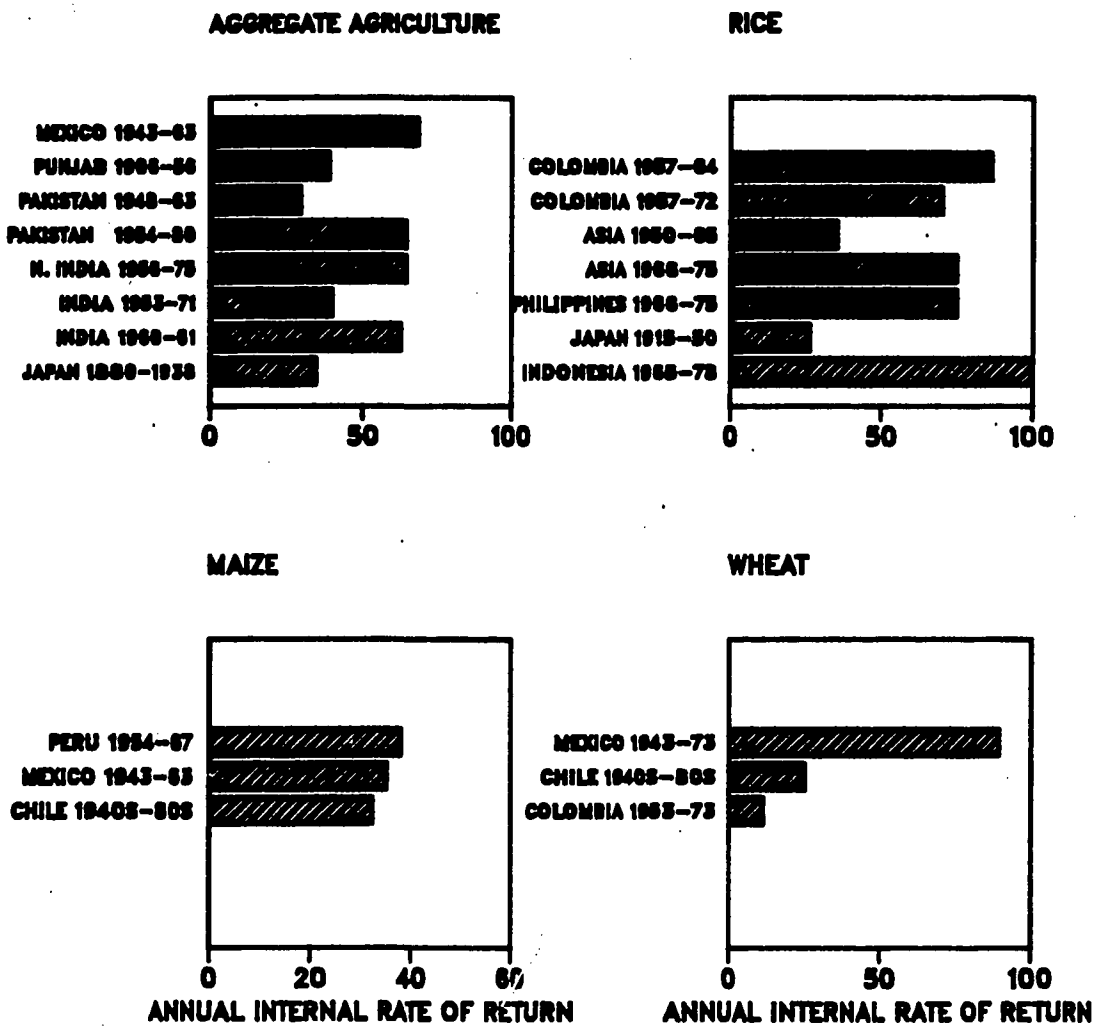
The presence of risk makes the evaluation of both past and future impacts a tenuous undertaking. When evaluating the impacts of past investment, attention is often focused on research for a commodity, or for a region, or on a particular project. This can lead to an inherent bias in which only the more productive projects are evaluated. In estimating future returns, some quantitative measure of the likelihood of success is necessary, but is rarely sought or available.

1.2.3 Return to investment

Agricultural research projects in developing countries whose payoff has been examined, have shown high rates of return. Even discounting the inherent biases and allowing for methodological difficulties, the evidence supports the claim that, in general, research expenditure has constituted a productive investment.

Results from several studies of research investment are summarized in Figure 1.3. The studies of aggregate research investment are perhaps the most interesting because they avoid some of the problems of concentrating on "successful" cases. In those aggregate studies, expenditures for all agricultural research activities are included in the costs and the benefits are measured as the productivity gains of the entire agricultural sector. Research in the aggregate has evidently been quite productive. Wheat, rice and maize research investments show similarly high returns. These data constitute those that were readily available and of seemingly acceptable quality. Doubtless, however, they represent selections of evaluations that their authors judged to be worthy of estimation which surely means that they are not representative of the universe of potential such estimates. It might

FIG 1.3
RATES OF RETURN ON INVESTMENT IN AGRICULTURAL RESEARCH IN DEVELOPING COUNTRIES



be speculated that comparable data on African national programs or on other staple commodities would not appear so favorable to research.

Knowing that the returns to selected projects have been high is perhaps reassuring, but it does not explain why the returns have been so variable, nor how the return should be partitioned between research investment at home and that undertaken elsewhere. Even more tantalizing has been the failure to explain the apparent persistent underinvestment in research. If the rates of return exceed the opportunity cost of capital by five or even ten times, increased investment and a falling rate of return over time could be anticipated. In fact, the recent increases in research expenditures in developing nations may be viewed partly as a response to the reported high rates of return (such as summarized in Figure 1.3). If so, it may be that future realized returns will be lower than for some of the earlier investments. Such would be the case if there were diminishing marginal returns to additional research and should not be taken necessarily to reflect less effective or less relevant research.

Diminishing returns need not be a feature of research if it can be sufficiently imaginative in conception and dynamic in organization. If nature is, however, increasingly niggardly in revealing her secrets, it is conceivable that the return to investment in research in a particular field will decline over time. Having made the presumably easier discoveries first, the amount of new knowledge contributed from a given increase in research expenditures may become successively smaller. Alternatively stated, ever increasing amounts of investment in research may be required to maintain the same rate of technological change through time. One explanation of why studies fail to show such a decline in returns to research is that increasing

basic knowledge continues to raise the returns to applied research in such a way that in total returns remain high.

It is difficult to predict the rewards of research but given the history of investment in quality organizations that are dynamic and responsive to emerging opportunities, it is reasonable to expect positive returns. Any tendency to diminishing marginal returns to research may be offset by advances in research methods. New breeding techniques, better instrumentation, advances in genetic engineering, expanded computing power, the introduction of satellite imagery, or new institutional arrangements for collaborative research, for example, all represent potential ways to maintain or increase the productivity of investment in research. The continual search for technological changes to improve the ways that research is conducted is a challenging task for those concerned to maintain the high rates of return to investments in research.

1.2.4 Arguments for public support of research

Excepting for work on agricultural chemicals and pharmaceuticals, organized agricultural research has been largely a public enterprise since its inception some 100 years ago. A number of key reasons are suggested for the willingness of the public to support research for agriculture while generally being unwilling to support industrial research to the same extent (Ruttan 1982). First, the benefits generated by agricultural research products that can readily be reproduced biologically (like new crop varieties), cannot, in general, be captured by the inventor. Without the existence of plant patents and the ability to enforce them - both rare in the developing countries - seeds of new varieties can be multiplied by anyone and sold without compensating the inventor. An exception is the development of hybrids which

are the offspring of two or more pure inbred lines. Reproduction of the hybrid seed is impossible without access to the parents, and this encourages private investment in plant variety development. Plant patents do the same thing, but are difficult to enforce and even, in the United States in 1982, about 40 percent of the private plant breeding was on hybrid maize. Patentable horticultural crops attracted 20 percent of private plant breeding (Kalton and Richardson 1984).

In general, when research cannot be appropriated by an individual or a single firm, some form of collective action is necessary to support the funding of research. This can take the form of producer organizations which levy their members and either conduct or fund research relevant to that industry. Colombian research in rice, sugar and coffee is supported in this manner.

The second argument for publicly supporting research is that, because many countries protect their domestic markets from imports, the benefits generally flow from the agricultural sector to consumers in the form of lower food prices. In the case of countries where food prices are determined in the world market, it may be in the interest of producers to support research because they gain any benefit of lowered costs. It is also in their interests to prevent export of the research findings that may have generated such benefits. However, knowledge is difficult to monopolize and, if it lowers costs in one country, it will probably do so elsewhere, thereby reducing costs generally and eventually also world prices.

A third argument is that there is a synergistic effect between education and research that benefits society in general, and therefore public univer-

sities engaged in teaching should also be involved in research. Still another argument of particular force for developing countries is that public investment in agricultural research contributes to maintaining or enhancing a competitive structure in the agricultural sector and that this benefits society at large. This argument encapsulates the wider ranging discussion of technological change and the role of the agricultural sector in development (section 1.1.1).

1.2.5 External effects of research

Research directed at a given commodity or region may produce results applicable to other crops or regions. There may thus be a tendency to spend too little on research because only some of the benefits accrue to the jurisdiction which finances the research. It is to be expected that groupings would emerge amongst regions or countries aimed at capturing these external effects within the taxing jurisdiction. In fact, this in part explains the emergence of regional collaborative research networks. The CGIAR system itself is an institutional innovation arising in part through such external effects.

1.3 Rate and Direction of Technological Change

1.3.1 A mixed record

The pattern of productivity growth in agriculture has been quite uneven. Some nations, regions or commodities have experienced sustained rises in productivity, while little or no progress has been made in others, at least in recent decades. Over the past two decades, for example, yields of maize have risen in Brazil and Argentina, but changed little in the Andean zone; rice yields rose in Colombia but not in Brazil; potatoes yields rose in Mexico but

scarcely at all in Peru. Table 1.2 shows the pattern of yield changes in some important crops in the countries in which Country Case Studies were launched.

In Africa, rice yields were stagnant except in Cameroon and Nigeria, maize yields were stagnant except in Burkina Faso, Malawi and Zimbabwe and potato yield increased only in Tanzania. In Asia, rice yield increased in every country except Thailand and Nepal, but maize yields increased only in Indonesia, China and Burma. Potato yields increased dramatically in China and less in other countries. In Latin America, rice yields have increased in Chile, Colombia, Costa Rica and Mexico, maize yields have increased in every country, sorghum yields have been stagnant, and potato yields have increased modestly in every country except Cuba where the increase was dramatic.

What are the key factors which explain this disparate and fragmented pattern of innovation and modernization? Knowledge of answers to questions such as this would contribute to more enlightened debates about the role of international research and the associated transfer of technology, about the past performance of the investment in international research, and about expectations for future contributions.

The literature both in the social and technical sciences contains many references to the uneven progress. Some cite the varying strength and quality of national research systems; others the wide differences in the stock of knowledge about different crops and animals. Some argue that the research systems have produced technologies relevant to some but not other circumstances, whether such biases be accidental or the result of conscious decisions. If they were so consciously chosen, did that reflect the relative political power of some group to influence the rate and direction of research

Table 1.2 Yield of some principal crops[a] in selected countries[b] (t/ha)

	Rice		Maize		Sorghum		Potato	
	1969–71	1979–81	1969–71	1979–81	1969–71	1979–81	1969–71	1979–81
Sub-Saharan Africa	1.36	1.37	1.00	1.00	0.66	0.67	6.25	6.99
Burkina Faso	0.88	0.81	0.65	1.01	0.50	0.65	–	–
Cameroon	0.81	1.98	1.15	0.86	–	–	2.70	1.79
Ethiopia	–	–	1.07	1.03	0.87	0.91	5.37	6.15
Kenya	4.50	4.50	1.49	1.56	1.07	0.99	7.10	7.47
Malawi	1.00	0.93	1.03	1.22	0.73	0.97	3.40	3.56
Nigeria	1.29	1.99	0.87	0.90	0.65	0.63	3.85	5.60
Senegal	1.30	1.21	0.81	0.82	–	–	4.00	5.00
Tanzania	1.19	1.35	0.81	0.62	0.50	0.63	3.85	5.60
Zimbabwe	–	–	1.49	1.70	0.36	0.65	11.00	11.33
Asia	1.84	2.19	1.11	1.27	0.49	0.70	8.89	11.63
Bangladesh	1.68	1.98	1.00	0.50	1.00	1.00	9.91	9.58
Burma	1.71	2.55	0.62	1.24	–	–	4.44	4.76
China*	3.29	4.23	2.03	3.01	1.59	2.43	9.25	40.62
India SAT	1.67	1.89	1.05	1.11	0.48	0.70	8.95	12.58
Indonesia	2.35	3.32	0.97	1.43	–	–	6.19	9.39
Nepal	1.94	1.83	1.81	1.49	–	–	5.41	5.55
Philippines	1.66	2.20	0.81	0.95	–	–	7.33	8.00
Thailand	1.95	1.94	2.57	2.12	2.73	1.29	9.00	7.00
Latin America	1.71	1.94	1.43	1.82	2.03	2.70	8.48	10.48
Brazil	1.43	1.44	1.37	1.69	2.00	2.13	7.28	10.81
Chile	2.61	3.16	3.10	3.80	–	–	9.30	10.31
Colombia	2.91	4.35	1.25	1.38	2.39	2.22	10.37	12.87
Costa Rica	2.00	2.72	1.12	1.61	1.83	2.10	9.00	9.11
Cuba	1.88	3.13	0.85	1.24	1.00	1.00	9.22	18.35
Ecuador	3.00	2.99	0.77	1.05	–	11.91	10.53	12.55
Guatemala	4.09	4.17	1.12	1.54	0.92	1.55	4.00	4.06
Mexico	2.57	3.47	1.22	1.71	–	–	10.63	12.82
Nicaragua*	2.96	2.16	0.92	1.10	1.02	1.21	–	–
Peru	4.15	4.46	1.62	1.81			6.41	7.52
Middle East and North Africa	3.71	4.35	2.33	2.61	0.81	0.79	12.21	14.47
Egypt*	5.27	5.63	3.74	3.85	–	–	16.53	17.37
Syria	–	–	1.33	2.24	–	1.40	12.40	15.57
Tunisia*	–	–	–	–	0.54	0.42	7.67	11.53

a Source: FAO data base.

b These countires were chosen for conduct of Country Case Studies (elaborated in Part II) but it was not posible to complete the work satisfactorily in all cases (asterisked).

in its favor? Or was it that, for some areas and crops, it was easier to achieve more rapid improvements through research than in others? Still others focus on the wide disparities in economic climates. They argue that, regardless of the relevance of the research results, the farmers' incentive to innovate has been so dulled by distortions in prices that poor productivity growth is a predictable consequence of unfavorable, discriminating policies. They contend that, where those policies have been favorable the derived demand for technical change has created a supply of innovations.

To respond to these questions is difficult in the absence of a structure which relates the technological issues to the broader political and social context that both constrains and determines them. Some elements of such a structure are identified in following sections and chapters but, in the context of the study, are dealt with most comprehensively in a companion paper by de Janvry and Dethier (1985).

1.3.2 The generation of new technology

Many national research programs were created in the 1950s and 1960s, partly in response to the pressures arising from industrialization. Growing urban populations and the need to hold down industrial labor costs created a need for increased food supplies. These pressures were reinforced by stagnating output as the agricultural sector responded predictably to the heavy implicit taxation of the policies. Public investment in agricultural research was supported by non-farm interests. Public research systems had in large part a monopoly on the generation of agricultural technology. As the possibility for expanding output by increasing the area cultivated became more and more limited in many countries, attention was focused on increasing the

productivity of existing land in order to produce more food, adding to the impetus for investment in research.

The economic gain that a particular group expects to derive from new technologies is a key factor in explaining the demand for change. The particular structure of production and the nature and importance of the commodity will determine how these demands are actually transformed into the supply of new technologies and institutions.

As wheat and rice were so important in the diets of so many people in developing countries, national research efforts were initially concentrated on them; furthermore, they were the first crops for which a formal international research system was evolved. Because the more important food crops were produced in areas of increasing land scarcity, the research focused on producing new technology which raised output per hectare. These areas were more densely settled and were better serviced by roads and markets needed to supply inputs, and take up and process the output. The cost per farm of supplying information about new technology is lower in densely settled, relatively homogenous areas. The costs of the research also tend to be lower in more homogenous areas, as fewer cycles are needed to test and validate new technology for zones that have less variable climatic and soil conditions.

In summary, the combination of both the demand and the supply forces led to yield gains in major food crops in favored environments. For those crops in other environments, and for less important crops, neither the forces of supply of nor demand for technological change were so propitious. This meant that subsequent attention of international centers to other crops and areas has not necessarily been backed by the same indigenous forces which favored

the earlier advances. Attempting to generate high yielding technologies for other crops and ecologies is not necessarily an appropriate strategy. For instance, relative factor scarcities in Africa differ markedly from those of Asia. For while relative land scarcities in Asia required new technologies that raised productivity per unit of land (e.g., seed and planting materials), land-surplus Africa with its high set of farm wages requires increases in productivity per unit of labor. This implies that, for the concerned, usually newer, international centers, there is a demand for new technologies that address relative factor scarcities that are different from those tackled by the first generation of centers.

Modernization of agriculture implies an increased role for purchased inputs and services. Their rise in importance relative to land and labor has characterized agricultural advances wherever they have occurred. This phenomenon is illustrated by the data in Table 1.3 which show the use of inputs for agricultural production in the major developing areas of the world. Land and labor in agriculture have increased rapidly in Africa and other developing Asia but have increased more slowly in China. Fertilizer use has increased extremely rapidly in Asia, but much less rapidly in Africa. Other inputs have had intermediate rates of change. These changes in inputs reflect changes in both the conditions of agricultural production and the availability of the inputs.

In the period prior to the Second World War, institutional changes which led to new research were often induced in response to specific crises such as a disease (in Colombian sugar) or changes in export markets (rubber). The widespread effort to industrialize in the post-war period created some demands for modernization of the agricultural sector. Growth of output was needed to

Table 1.3 Use of major inputs in agricultural production in developing country regions 1960s and 1980s

Region	Year	Land[a]	Labor[c]	Fertilizer	Draft Animals[d]	Machinery[e]
		'000 ha	'000	'000 t	'000	'000
China	1969-71	102.2	268.3	4.3	93.1	0.144
	1980	99.2	276.5	12.8	95.5	0.766
India	1969-71	164.7	153.8	1.9	236.8	0.112
	1980	169.1	165.9	5.0	246.5	0.419
Other developing Asia[b]/	1969-71	102.9	126.9	3.0	115.8	0.104
	1980	111.5	142.8	7.5	133.8	0.321
Middle East and North Africa	1969-71	84.6	31.8	1.1	60.7	0.208
	1980	87.3	34.9	3.0	72.7	0.645
Sub-Saharan Africa	1969-71	139.5	87.6	1.7	147.2	0.165
	1980	150.2	100.8	1.2	162.1	0.226
Latin America	1969-71	146.4	36.5	2.9	255.2	0.725
	1980	162.1	39.0	6.8	305.5	1.012
All developing countries	1969-71	741.5	706.2	13.3	909.3	1.463
	1980	780.6	759.4	34.2	1016.7	3.305

Source: FAO Production Yearbook 1981 and FAO Fertilizer Yearbook.

a Arable and permanent crop land.

b FAO's categories of Far East plus Asian CPE less India and China.

c Economically active population in agriculture but not that national data generally do not include non-market agricultural labor of women and children and exclude a undercount part-time/periodic wage work of women in agriculture.

d Horses, mules, asses, cattle, buffalo and camels.

e Number of agricultural tractors plus harvesters and threshers in use.

provide food for an expanding non-farm population and to generate foreign exchange receipts to pay for the capital goods and raw materials needed for the industrial sector. National research programs were formed, reorganized and strengthened, with political support drawn from the industrial and commercial interests. The national programs played an important role as technological "converters" who facilitated the testing, adoption and dissemination of technologies available internationally. The early work of the centers fitted well with this model. In the past decade, however, some of these programs have failed to receive sustained and effective support from often increasingly hard-pressed governments.

The use of purchased inputs leads to a potentially greater role for private research and development and for the development and consolidation of corporate producer organizations. These groups will tend to assume more control over the generation of technological change as a larger share of the benefits is able to be directly appropriated. With various research groups competing for resources, the role of public agencies diminishes as international, private and producer organizations assume greater importance. National programs tend to become weaker in these circumstances as their priorities and clientele change. Their staffs are attracted away to employment by the private sector and international agencies. Whereas the early collaborative efforts of the centers were almost exclusively with public research agencies, the modernization of agriculture leads to a more fragmented and diverse institutional setting. This requires that the centers form wider and different collaborative arrangements with university consortia, with development corporations, with seed and feed companies and other private firms, and with producer associations. The generation of new technology takes place in a multiorganizational structure in which the public agencies are only

one part. At the same time, however, the increasing importance of market mechanisms for the orientation of technological change leaves certain groups of producers successively more isolated from the dynamic part of the sector. When these social classes are too weak to mobilize and coordinate government action in their favor, their potential demand for technological change is not translated into an actual demand for research. Public agencies often - but probably too rarely - assume a mandate for a broadly-based approach to rural development in which improvement in social welfare becomes an important goal, and the generation and diffusion of new technology together constitute only one instrument for its attainment.

This continued evolution of the institutional structure of research means that the international centers must continually seek new and improved ways to collaborate with national systems in training, and in generating and diffusing new technology. When those linkages are in harmony with indigenous forces that generate the demand for and supply of new technologies, they will be more productive and less prone to rejection as "foreign transplants". Efforts by centers that are not in harmony with those forces will fail as surely as those that ignore the ecological or economic circumstances. As Chambers (1985) persuasively argues, effective harmony can be pursued most expeditiously by agricultural researchers, both national and international, "putting the last first", that is by developing structures and working styles through which research workers can learn from, and address the most pressing needs of, the resource-poor farmers of developing countries.

1.4 The Consequences of Technological Change for International Trade

International trade issues have been only briefly addressed in the preceding section so it is appropriate, before proceeding to broad discussion of impact assessment, to ask: what has been the impact of technological change on trade in basic foodstuffs? In this section, it is argued that there is not a meaningful, simple answer to this question. Trade and technology are inextricably linked, each influencing the other through a host of direct and indirect mechanisms. Only by placing the issues in a broader context of economic development can a proper perspective be achieved.

1.4.1 Background

For at least three decades starting in the 1930s, strong doubts were expressed about the role of trade in agricultural products as a development strategy. It was argued that, by their very nature, the demands for the agricultural exports of poor countries were both limited and likely to shrink over time. Simultaneously, the real cost of acquiring manufactured imports would rise, so that fewer units could be bought for a given quantity of exports. Given these circumstances, it was thought that the role of agricultural trade should be minimized.

A large number of countries gained independence in the 1950s and 1960s. Many had depended heavily on agricultural exports during colonial rule, and nationalistic pressure lead to a decline in the importance of these exports, in part as a rejection of colonial economic structures. Further impetus to this decline was added by the claim that poor countries were exploited in their trading relationships with the industrial world. Much of the impetus for the new international economic order arose from that view. Some of the

changes that were proposed were aimed at altering the nature of the international trading relationships.

During the 1970s, there was increased volatility in the prices of traded agricultural goods. Many countries expressed the need to place greater emphasis on domestic supplies so as to lessen their dependence on world markets.

As a consequence of all these forces, there has been heightened interest in the impact of technological change. Can, or does, increased domestic output reduce the dependence of a country in imports for its supply of basic foods? Behind this question is the belief that, as poor countries are chronically short of foreign exchange, a decline in food imports would release foreign exchange for other essential imports. In this way, the new technologies would contribute to overall economic development. Like all simple propositions, this is both superficially plausible and contains a germ of truth. However, the picture is much more complicated, and demands a broader approach. Before proceeding to that, the actual record is examined.

1.4.2 The record

There has been a remarkable growth of food transfers from industrial to developing countries. The demand for food has grown faster than production throughout the developing world, which is now importing three times more than it did a decade ago (Table 1.4). This has occurred despite the adoption of new agricultural technology, the spread of modern varieties and the growth in output they have engendered. Yields per hectare have risen at an annual average rate of nearly two percent in developing countries - a quite unprecedented result. In the late 1960s, net imports of basic food staples

Table 1.4 Net imports of basic food staples of developing countries (Mt)

Region	1968-70	1978-80	Change
Asia	+9.9	+7.7	-2.2
North Africa, West Asia	+4.2	+19.0	+14.8
Sub-Saharan Africa	-0.3	+6.1	+6.4
Central America	+1.1	+6.6	+5.5
Upper South America	+2.9	+9.9	+7.0
Lower South America	-8.7	-12.9	-4.2
Total developing countries	+9.0	+36.3	+27.3

Source: Paulino and Mellor (1984).

were 2.4 percent of production in the developing countries, about 9 Mt of basic staples; by the end of the 1970s this had risen to seven percent, which was over 35 Mt, and today it is almost 10 percent. In aggregate, the spread of new technology has raised production, but the growth of consumption has been even faster. Imports as a share of consumption and in absolute terms are higher now than two decades ago.

The aggregate pattern conceals marked regional differences, however; in Asia, absolute imports of basic food stuffs have declined slightly, and in lower S. America (Argentina, Uruguay and Chile) net exports continued to rise. The biggest increase of imports came in N. Africa and W. Asia. This region, which includes several oil-exporting countries, accounts for over one half of the increase in developing country imports. Likewise, Central America, the Caribbean and upper S. America had a substantial rise in food imports. The smallest absolute increase came from Sub-Saharan Africa. This is of note, as popular comment has focused extensively on the high food imports dependency of this region. Furthermore, its dependency is also the lowest in relative terms. The ratio in basic food imports to total consumption was computed for the period 1978-80. This ratio is 10, 20 and 25 percent for Sub-Saharan Africa, Central America and upper S. America, and N. Africa and W. Asia, respectively. While it is true that imports by Sub-Saharan Africa have continued to rise in the 1980s, these rankings remain unaltered.

The pattern of wheat trade has changed over the past two decades, as is shown in Table 1.5. With the spread of semi-dwarf varieties, the level and share of wheat imports into tropical countries and by the Middle East and N. Africa now account for 60 percent of total developing country wheat imports.

Some of the details of the changing pattern of rice trade are given in Table 1.6. The volume of world trade has almost doubled in the past 25 years. A number of traditional exporters (China, Pakistan and Thailand) have increased their exports significantly. Japan has become a net exporter as a result of high levels of protection, and the U.S.A has more than doubled its exports.

While total imports in monsoon Asia remained constant, imports of rice by Bangladesh, India and Sri Lanka, Malaysia and the Philippines fell appreciably. More recently, Indonesian imports have also declined. In all these areas, the spread of modern semi-dwarf rices has been significant. In contrast, rice imports by the Middle East and Sub-Saharan African countries have continued to rise.

1.4.3 Determinants of increased imports

Why have the relative and absolute levels of basic food imports risen in all developing regions outside Asia and lower S. America?
There are a number of reasons. First, population increase alone in some regions has outstripped the growth of output, and to prevent at least some of the decline in consumption per person, imports have risen.

The impact of new varieties, while leading to expanded production, may sometimes have little or no impact on imports or exports. The growth in population can be such as to absorb the entire increase in output with no change in traded volumes. Such was the case of rice in Colombia where, despite a truly spectacular rise in output following the introduction of modern rice varieties, there was no significant change in trade. All the additional rice was consumed domestically. Presumably, in the absence of the

Table 1.5 Changing pattern of wheat imports by developing countries

		1961-65	1970-72	1978-80
			Mt	
Total imports		24	29	52
			percent	
Shares:	India, Bangladesh, Pakistan	25	11	5
	Tropical countries	22	31	28
	Middle East/North Africa	19	25	31

Source: CIMMYT (1983).

Table 1.6 Changing patterns of rice trade (Mt)

Country	Annual average net volume of rice trade	
	1961-63	1978-80
Rice exporters		
China (PR)	0.56	1.15
Korea (DPR)	0.	0.31
Pakistan	0.22	1.01
Taiwan	0.01	0.30
Thailand	1.42	2.32
Japan	-0.18	2.32
Total Asia	4.18	5.98
World Total	6.77	11.26
Rice importers		
Bangladesh	0.48	0.28
India	0.42	-0.35
Korea (Republic of)	0.	0.34
Sri Lanka, Malaysia and Philippines	0.86	0.32
Total monsoon Asia	3.30	3.30
Middle East	0.31	1.75
Sub-Saharan Africa	0.44	1.82

Source: Siamwalla and Haykin (1983).

new varieties, a slower growth of domestic output would have caused internal prices to rise, and substantial imports may well have been needed to hold down prices.

Second, the prevalence of new national independence has altered the nature of the internal political forces which, when combined with structural changes in the economy and greater urbanization, has increased the demand for food. Again, in the absence of sufficient growth of domestic output, imports have assumed increasing importance.

Third, the rise in imports is a logical consequence of the continued long-term decline in world prices for some commodities. These prices have been influenced by technological change, by domestic policies and by international arrangements. For example, W. Europe's high protection of domestic agriculture increases the supply of poultry meat and dairy products on world markets, and provides developing countries with the opportunity to acquire additional food at lower real costs.

Long-term changes in relative prices alter the trading opportunities as is illustrated by the case of rice and wheat. About 1920, the world prices per ton for rice and wheat were approximately the same. By the 1960s, rice prices were double those of wheat. Today, they are roughly three times as high, although some of this "advantage" for wheat is lost when account is taken of further processing cost. Shifts in both the demand and supply explain this widening gap. Wheat output has grown more rapidly than rice over the past four decades, increasing the supply of wheat relative to rice. At the same time, population and income effects have increased the demand for rice relative to wheat in the rice areas of the world. China has, with due

regard to domestic costs of transporting grains, regularly engaged in foodgrain arbitrage, exporting rice and importing relatively inexpensive wheat. Other countries, not traditional wheat producers, have also increased their imports of wheat relative to rice. While urbanization may explain some of this shift, increased wheat imports reflect both a lower absolute price and a marked fall in the world price of wheat relative to rice.

Fourth, both the volume and value of food aid have declined over the past two decades, leading to the need for higher commercial imports by some developing countries.

Finally, the rise in income per capita is probably the single most important force that has shaped the patterns of world food trade, and it will probably assume an even greater role in the next decade. An expanded demand for food imports may arise in part from income growth generated by a successful modernization of agriculture; i.e., the spread of modern varieties of basic foods can generate additional income streams which create further demands for food. In short, a fast growth in food output in a developing country tends to generate further growth of imports of other foods. The relatively high rates of growth in food production in E. and S.E. Asia (4.3 percent per year) and Central America, including Mexico and the Caribbean (4.1 percent per year) are in areas where net food imports have also grown rapidly. N. Africa and the Middle East have also had high rates of imports generated by rapid rises in income.

1.4.4 The demand for imported feed grains

The rise in imports of livestock and feed grains is particularly marked. One way to capture this is to convert all livestock products to feed grain

equivalents, and then combine these with the trade in grain. These data are reported in Table 1.7. Two aspects are worthy of comment. The value of trade has more than trebled; net imports have grown by five percent a year for 20 years, and show no sign of decline. Second, significant changes in the pattern of trade have occurred. N. American and Australian exports together rose three fold, W. European imports fell as a consequence of protection to domestic producers and export subsidies. In all other regions, imports rose faster than production. This trend is almost certain to continue.

In 1982, poultry consumption in developing countries was 10 Mt. Population and income growth will result in an annual increase of demand of at least six percent so that, over 10 years, total consumption will rise to 18 Mt. Production of an additional 8 Mt of poultry meat would require 20 Mt of feed grains. Even if half of this were to come from domestic output, import requirements will still rise by 10 Mt per year to meet the growth in demand for poultry alone. Current feed grain imports of developing countries are about 14 Mt, so that major increases can be expected.

Major changes have taken place in the pattern of demand for grains, and this has led to corresponding changes in trade. Between 1961-65 and 1975-77 the growth rates in direct consumption per capita for the major food staples in developing countries were over 2 percent annually for wheat, less than 0.5 percent annually for rice, and negative for coarse grains, roots and tubers. The rise in imports and consumption of wheat is due to consumer subsidies, rising incomes, urbanization and lagging production of staples. For example, wheat output per capita has fallen in N. Africa, an area with the greatest growth in wheat imports.

Table 1.7 Net export of grains and equivalents from livestock production (Mt feed grain equivalent)

Region	1960	1980
North America	22.8	119.2
Australia and New Zealand	15.7	28.4
Latin America	10.3	24.3
Western Europe	-43.4	-27.4
Japan	-4.0	-32.7
Eastern Europe and USSR	5.9	-47.2
China	1.2	-5.9
Other Asia	-8.3	-28.3
Africa	1.8	-7.5
Total exports above	57.7	171.9
Total imports above	55.7	149.0
Annual carryover and statistical balance	2.0	22.9

While the use per capita of maize as a direct food grain has not changed over two decades, the demand for maize as a feed grain has continued to rise in developing countries. In the future, it is almost certain that the increasing demand for livestock products will lead to greatly increased demand for soybeans, maize and cassava as feedstuffs. This should provide a positive stimulus to domestic production in many countries. In others where the possibilities for growth in output are more limited, imports will continue to grow. The technology for the production of pork and poultry is both readily available and highly transferable, so that developing countries can readily acquire the imported technology for domestic production of these products, based on imported inputs.

1.4.5 The influence of economic policy

The domestic agricultural policies of both the industrial and developing countries have made the role of world trade smaller than it would have been in the absence of these interventions. At the same time, trade has been made much more unstable. A country which depends on world markets for supplying a significant part of its food needs may be at a disadvantage. New agricultural technology can ease the process of increasing domestic production, reducing dependence on world markets, and lessening problems of food insecurity. Instability in world food markets is also transmitted to the non-farm sectors of the developing countries with forced reductions in imports of capital goods and industrial raw materials in order to maintain food imports. Improved productivity of domestic agriculture, along with other primary export industries, may thus also help to stabilize purchase of those imports necessary for stable growth and employment in the non-farm sector.

The process of economic growth involves three key ingredients: technological change, investment in human and physical capital, and increasing dependence on purchased intermediate inputs. The income streams generated by economic growth are spent largely on consumer goods (e.g., textiles, radios), on building materials, and on foodstuffs (e.g., livestock products, vegetable oils, fruits and vegetables). Many countries will increase their imports of both consumer goods and of fertilizer, metals, machine parts, fuels, chemicals and pesticides - and thus increase their dealings with the typically large multinational corporations that dominate some of these industries. Command over foreign exchange must continue to grow in order to sustain these imports. Often this is generated by agricultural exports. If these are not adequate, they can act as a brake on economic growth.

As economic growth proceeds, the structure of comparative advantage may well change. Increased industrialization and rising labor costs may raise the domestic resource costs and result in higher imports (or fewer exports). These dynamic changes in comparative advantage will result in changed trade patterns. Furthermore, changes in real exchange rates arising from both real and monetary forces impinge directly on trade in agricultural products. A strong U.S. dollar will reduce the importance of U.S. exports in supplying food to developing countries, and stimulate production and trade in other countries which become more competitive as a result of a relative weakening of their currencies. What appear to be small changes in the relative prices of currencies have immediate and significant implications for the pattern of comparative advantage in agriculture. Thailand, Brazil, Ivory Coast, the Philippines and Malaysia are all examples of countries which at times have taken advantage of expanding world trade, exchange rate movements and technological changes to expand their crop exports. In contrast, for

examples, the poor performance of Mexico's agricultural sector and its increased dependence on food imports reflects in part the unfavorable incentives stemming from exchange rate policies.

Successful economic growth in agrarian developing countries involves technological change as a necessary condition, and increased imports of inputs and also of agricultural products as a consequence. In short, the role of trade often expands, not lessens as a result of the successful development of new agricultural technology.

1.5 Assessing the Impact of Research

1.5.1 Goals

Within the CGIAR, it is evident, and indeed it is a stated objective, that a continuing review of the priorities related to the needs of developing countries is receiving, and will continue to demand the Group's most critical attention, in order to enable it to adjust its support policies to changing needs. When there exists a unidimensional goal of increased output through the enhancement of agricultural productivity, the determination of priorities and research strategies is, at least conceptually, a relatively straightforward matter. This assertion in no way diminishes the complexity of the task, when problems of determining the probabilities of success and the likely lags involved are duly recognized. What is evident, however, is that when research is viewed as an instrument for achieving broader social objectives, the problem of the selection of appropriate strategies and weighting of competing ends becomes vastly more difficult. Further, there can never exist a statement of objectives and priorities that in any sense is immutable. The very nature of technological change is that it disturbs existing productive

and economic relationships - should it fail to do so, would constitute a failure.

A clear understanding of the goals of research is a prerequisite, not only for the efficient allocation of research resources, but for any evaluation (ex post or ex ante) of the impact of the research. To begin to consider impact requires an answer to a question as basic as: "the impact of what on what?" Is it the impact of research on expanding the set of technologically feasible alternatives? Is it the impact of that new technology on enhanced agricultural output and productivity? Is it, in turn, the impact of greater productivity on economic growth? Is it the impact of research through improved productivity and economic growth on human welfare? Is welfare to be judged in terms of the distributional impact on incomes of producers and consumers, as well as (or in place of) aggregate real growth of incomes?

The same set of questions can, of course, be posed in relation to assessing the past impact of the centers. For simplicity, however, it might be argued that it is merely the consequences of the technology that are being assessed, with no explicit statement of the past goals. But, it becomes difficult to divorce the mere examination of the consequences from implicit judgments about what the nature of the impact should have been. For example, if it is the case that the real wages of agricultural labor did not increase in regions experiencing rapid technological change, this could be viewed as a simple statement of the consequences. But there is a possibility that some will view the welfare of the landless as a primary goal, and who will hasten to point to any failure of the introduction of modern varieties to augment the incomes of this group. The "green revolution" in essence, has been a limited

number of new varieties of rice and wheat with enhanced capacity to utilize water and fertilizer. The expression is, however, perhaps an unfortunate one since the connotation of revolutionary change has spawned the expectation that new technology, generated through investment in research, represents a mainspring of balanced and equitable agricultural growth within the complex process of economic development - in short, an instrument with which to ameliorate social ills.

1.5.2 Efficiency and equity

Rates of return constitute a readily comprehended index of the social profitability of investment in research. When calculated for historical periods they answer the question: did the investment of scarce public funds generate a return greater than that which would have accompanied an alternative use of the resources? With appropriate assumptions, a similar approach can yield estimates of the potential return to planned investment.

Analyses of aggregate costs and benefits, appropriately discounted to reflect the lengthy lags involved, provide an encouraging background against which to foster the continued support of the international agricultural research enterprise, but they represent only one dimension of social accounting: that of economic efficiency. While it can be argued that such efficiency is a valid criterion against which to measure the social profitability of the use of scarce resources, it has become evident that it is not a universally sufficient yardstick, or perhaps even a necessary one. For more than a decade, explicit concern for welfare of the lower income groups has become an important and recurring theme in discussions of economic development and role of the international lending and donor community. The international centers have been seeking to articulate their goals and philosophy to reflect

this concern. Both in their mandates and in the structure of their research programs, evidence is found of the perceived need for technological change to address both efficiency and equity goals. The more traditional production-oriented philosophy has come under increasing need to place greater importance on the geographic and social distributional implications of technological progress in agriculture. More recently, the issue of food security has been added to the agenda of goals to which agricultural research might be addressed. The search for so-called "scale-neutral" technologies (or even technology biased for certain classes of producers), and the notion that there exists a "trade-off" between achieving maximal gains in agricultural productivity and real income gains for specified groups have permeated the discussions of investment in research to generate technological change.

It should perhaps be stressed that the very impetus for the formation of the CGIAR was to encourage more research to assist developing nations increase the quantity and improve the quality of their agricultural outputs and thus raise living standards. That the system has chosen to direct its support to research on the basic food crops and livestock which comprise the diet of the majority of the population in the tropical zones strongly implies, in and of itself, a belief in the potential contribution of technological change to real income growth of the poorest of the poor. Food expenditures comprise such a large proportion of the total outlays of the lower income groups that it is virtually axiomatic that strategies aimed at lowering the real cost of foodstuffs will confer a disproportionate benefit on these groups. However, the force and simplicity of this argument is threatened as soon as recognition is given to the existence of low income producers as well as consumers, to the inequality in the ownership of productive resources, and to apparent

imperfections in input markets, all of which can result in unequal access to the bounty of technological change.

Clearly, research that leads to new production methods has economic and social implications. In fact, as noted, technical change in agriculture has historically been a, if not the, predominant force in the growth of real incomes. Without advancement in the productivity of agriculture, resources cannot be released from fulfilling the fundamental requirements of food and clothing. A better understanding of the linkages between technology, improved productivity, economic growth and, ultimately, human welfare, is a prerequisite for establishing realistic expectations, and hence goals, for the contribution of research. As soon as the planner ventures beyond the confines of a single objective such as "increasing rice yields" or "increasing the output of cassava," and adopts a mandate which includes "accelerating agricultural and economic development" or "improve the diets and welfare especially of producers and consumers with limited resources" an understanding is required of mechanisms whereby research, whose immediate product is simply new agricultural technology, can have an impact on these goals. Once the linkages are understood, the constraints can be identified and, for given priorities, the most anticipated efficient research can be specified.

Should the objectives also include raising the real incomes of small-scale producers of energy-intensive commodities, there is the added complication that alternative research strategies may (and, generally, most surely will) have differential impacts on the two objectives. To overcome this a set of weights is needed that reflects the relative importance to be attached to each of the objectives and permits the formation of a single index or criterion against which alternative strategies can be evaluated. The CGIAR

has reached a consensus on the importance of generating new technology for a range of basic foodstuffs, and has continually sought out those areas of the research process for which there is greatest advantage from international support. With the mounting concern for investing in research that might fulfill more specific distributional objectives, the Group has both the opportunity and the obligation to provide a forum for discussion and exchange of information among members in order to enhance the articulation of the ultimate goals of research. In all likelihood, the centers will be subject to continued questioning about the distributional consequences of their research strategies. If research goals are not clarified efforts to achieve the best use of the limited research resources may well be confounded if not frustrated.

The Panel of reviewers from the developing countries felt that the above discussion of efficiency and equity criteria did not go far enough. It counselled the inclusion of two additional criteria for the sake of completeness. First, it may be important to distinguish between explicit and implicit objectives of incremental food production. The political leadership in a developing country may seek new technology not necessarily to increase food production per se, but to increase marketed quantities and surpluses to satisfy the needs of the vocal and politically volatile urban minority. Some may seek to measure research impact in terms of such implicit objectives as reduction in urban food riots, enhanced rural-urban social harmony, reduced rural-urban migration and greater political stability, to mention a few. Second, the explicitly stated objectives of research programs may not be the important ones, viewed in national eyes. One contender, for example, is the potential use of agricultural research for attaining food self-reliance and food self-sufficiency. Self-reliance as a societal objective and aspiration

is being increasingly used to set agricultural research priorities and many countries may come to view the relevance and the impact of the centers in terms of their contribution towards the realization of self-reliance.

1.5.3 Multiple outputs

The early efforts of the international centers were focused on improved germplasm, and even today, this work forms the central part of the activities of most centers. But it is far from the only product of the centers. Others relate to crop production and husbandry; crop harvesting, processing and distribution; and the provision of improved seed and techniques for rapid multiplication. Yet another set of products of the centers relates to their contributions toward increasing the capacity for research in national programs, the organization and management of research, the training of researchers, the development of research techniques and the construction and management of experimental field sites. The research results from studies on food and agricultural policies that contribute to public debate and decision making are yet another dimension of the products of the system. As the system has grown, goals and activities have been added, making it difficult to associate activities of the centers with objectives in any simple manner.

1.5.4 Collaboration

The centers have never been conceived as independent entities but rather as parts of a linked, global system of agricultural research. They operate in collaboration with universities and leading public and private research centers in both industrial and developing countries and in this way serve as committed intermediaries in channeling the results of fundamental research discoveries to partner institutions in the developing countries in which they

work. For this reason, the very notion of identifying the "impact of the centers" in isolation from that of their many partner institutions in agricultural advancement is something of a contradiction of a premise of their very existence.

1.5.5 The counterfactual problem

When endeavoring to assess the achievements of the centers it is necessary to speculate on what would have to come to pass in their absence. One means of avoiding this difficulty would be to argue that the centers must, by implication, have represented a better investment than alternative uses of funds. It might be held that rational donors seeking the maximal effect from scarce resources would support the centers only if they judged this to be the case. But such argument is inherently unsatisfactory.

Certainly the funds have other uses and could have been invested in many other ways - directly in bilateral assistance to national programs; indirectly through domestic research agencies which establish collaborative research in developing countries; or through regional research networks. The relevant comparison is then the world with centers versus the world as it would have been with one of these alternatives. But which one? There would surely be endless debate about the validity of any one or any arbitrary combination as a base for comparison. There seems to be no satisfactory answer to this problem, and the approach taken is not to dwell too much on any counterfactual assumptions about hypothetical possibilities, but rather to describe the process of the collaborative endeavors including the CGIAR centers and the significance of their achievements and potential.

1.5.6 This study

In an effort to contribute to the needed debate, this report is focused on a review of the impact of technological change in agriculture, with specific reference to the contributions of the international centers. By an examination of primarily past impacts, some insights should be gained as to the contribution of research to enhanced productivity, and to its economic consequences.

A comprehensive view is sought. It is recognized that many expectations for the impact of the CGIAR centers are unrealistic. The centers cannot transform the agricultural research and agricultural production sectors of the scores of developing countries that seek such transformation; they can, however, contribute to the process. They cannot ensure that the social and economic settings into which technologies are placed are such that the gains from technological advance accrue to those most in need of such improvement; they can, however, refrain from developing technologies that directly substitute for the services or inputs supplied by such groups in the production process. They do not have the leverage to induce developing countries to change economic or social policies that reduce the incentives for farmers to use new technologies that might result in lower food prices to consumers; they can, however, evaluate the likely consequences of alternative policies and bring these to a wide audience.

Thus, the goals against which the CGIAR centers are measured in this study are two: (a) to assist developing countries to improve their capacity to conduct relevant agricultural research, and (b) to contribute to increases in food production and welfare through the results of their research

activities. The continuing ability of the centers to meet these goals in the future is a further concern in the study.

In order to reflect the degree to which the centers have met the first goal, an examination is made of: what has happened to the agricultural research establishments of the developing countries, and how those developments may have been affected by the centers; the views of individuals in the developing countries who should be knowledgable about how the centers have contributed; the human resource development activities of the centers, especially training; and the direct activities of centers in assisting countries with institutional development.

The extent to which the centers have assisted increases in food production and welfare is reflected in data on the extent to which technologies or components of technologies developed by and with the centers have been accepted by countries and by farmers; the extent to which center research has provided evidence on the effects of economic and social policy on on food consumption; and evidence on the extent to which technologies toward which centers have contributed have benefited different groups in society.

The extent to which the centers will have the ability to contribute on a continuing basis to meeting these goals is addressed through an examination of their performance in several fields that are thought to be central for future impact, including germplasm conversation and utilization, the matching of technologies to ecologies, the management or otherwise of agricultural pests, the development and management of tropical land, and biological nitrogen fixation.

1.6 Coda

* Technological change in agriculture has been a mainspring of economic growth. Only if the constraints to growth are relieved by new factors of higher inherent productivity will agriculture become a major source of growth in a modernizing economy.

* Between 1961-65 and 1979-83 cereal production increased at between 1.5 and 4.6 percent annually across the major developing regions, with the slowest rate in Africa and the fastest in China. Root and tuber production increased at between 1.0 and 5.7 percent annually, with the slowest growth rate in Latin America and the fastest in India. There are good prospects that food production will continue to exceed population growth in developing countries as a whole but there are prospects that local difficulties will continue.

* Developing countries, especially those with rapidly growing populations, continue to become increasingly dependant on imported food. Food imports by much of the developing world must continue to rise over the foreseeable future, but this in itself does not imply that research has not had beneficial impacts.

* Yield per hectare became, and remains, a quick and easy index of agricultural progress, but there are serious limitations to its use. Land is not the critical limiting resource of all areas and, accordingly, other measures of partial productivity should be used as is appropriate.

* The products of research may be relevant for improving yield stability, and for allowing more intensive production by shortening the growing season. Research may also reduce costs and extend the domain of a crop to areas previously unsuited because of diseases or growing conditions.

* Expenditure for agricultural research is a form of investment. Long lags imply the need for sustained research funding over lengthy periods. Some agricultural research projects in developing countries have shown high rates of return. Research in the aggregate has evidently been quite productive. The pattern of productivity growth in agriculture has been quite uneven.

* The willingness of the public to support research for agriculture has several explanations but the most important is the fact that agricultural research products that can be biologically reproduced yield benefits that cannot be captured by the inventor.

* Research directed at a given commodity or region may produce results applicable to other crops or regions. The CGIAR system itself is an institutional innovation arising in part through such external effects.

* The strength and quality of national research systems vary greatly. Many national research programs were created in the 1950s and 1960s in response to the pressures arising from industrialization. Growing urban populations created a need for increased food supplies.

* As wheat and rice were so important in the diets of so many people in

developing countries, international research efforts were initially concentrated on them. The demand for new technology was focused on the major food crops. The cost of generating and diffusing that technology was lower for more favored, densely settled environments with increasing relative scarcity of land.

* The growth in productivity, in part fostered by the increased investment in research, has not made developing countries as a whole less dependent on food imports. In fact, most regions now import more food than a decade ago. In the late 1960s, food imports by developing countries were 2.4 percent of domestic production; today they represent over 10 percent. This growth will continue through the very process of economic advance arising in part from improved agricultural technology.

* Modernization of agriculture implies an increased role for purchased inputs and services. Their rise in importance relative to land and labor has characterized agricultural advances wherever they have occurred. A future research priority would be to reduce costs per unit of output without reducing yields.

* When research is viewed as an instrument for achieving broader social objectives, the problem of the selection of appropriate strategies and weighting of competing ends become vastly more difficult. Explicit concern for welfare of the lower income groups has become an important and recurring theme in discussions of economic development and the roles of the international lending and donor community. There are also scientific goals that serve a variety of social objectives: nutrition, lowering costs of production, employment, environmental improvement, etc.

* Research that leads to new production arrangements has many economic and social implications. The centers will be subject to continued questioning about the distributional consequences of their research strategies. This is as it should be. However, the scientific agenda has the potential for results that offer broad social benefits. By an examination of past impacts, some insights can be gained as to the contribution of research to enhanced productivity, and to its economic consequences.

* The centers are conceived of as parts of a linked global system of agricultural research. The very notion of identifying the "impact of the centers" in isolation from that of national research, development and extension organizations is a contradiction of a premise of their existence.

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2 THE WORK OF THE CENTERS

2.1 Introduction

The CGIAR centers constitute a heterogenous group of institutions of varying ages and sizes, each with a different organization and operational objective, depending on when, how and by whom each was set up. IRRI, CIMMYT, CIAT, and IITA were established, operating centers when the CGIAR was formed in 1971. Two others, CIP and WARDA, were subsequently incorporated in the CG as functioning entities. The other centers were established through the active participation of the CGIAR, but the Group has been flexible enough to design those centers so as to be responsive to perceived needs rather than to an institutional formula. The result is considerable diversity.

A guiding force in the establishment of the first international centers was their initiators' faith in them as an appropriate novel instrument in international agricultural development. This faith was not shared by all or even most developmentalists in the late 1950s and early 1960s. It took considerable insight and courage to break with received wisdom to pioneer a new strategy for facilitating the advance of agricultural productivity in the developing world. The thinking that went into the formative plans was based on some key ideas including:

(a) A growing recognition that tropical agriculture is different from temperate agriculture and does not benefit readily from attempts to transfer temperate zone technology.

(b) A rejection of the notions that peasants are irrational and that low agricultural productivity in the tropics arises from illiteracy and irrationality.

(c) Scepticism regarding the claims of agricultural scientists, especially those working on rice and wheat, that improved technology in the form of cultivars and practices existed, and merely awaited an adequate development of extension services.

(d) A belief that, if a critical mass of scientific research to exploit plant genetic potential was to be realized in an 'acceptable' time frame (say within two decades), that a new development strategy would be necessary founded on 'mission oriented' crop-based multidisciplinary research. Experience in Mexico, India and the Middle East in the 1950s convinced the decision makers that this could not be achieved quickly within the existing bureaucratic and disciplinary structures of national agricultural research systems. This was felt to be so because:

(i) national systems often do not easily accommodate research based on agro-climatic zones that cross political boundaries;

(ii) the existing national systems, both in the developing and in the industrial countries, were in the main, discipline rather than crop oriented and seemed to have little interest in the 'psuedo-

scientific' approach of research on farmers' fields as opposed to laboratory research: and

(iii) national systems were not organized in the most effective way to utilize the scarce skills of plant breeders, agronomists, and entomologists.

(e) A confidence that centers addressed to crop research for agro-ecological regions could exploit the comparative advantage to be had by concentrating on those research aspects with the greatest externalities, i.e., improving the productivity of crops that are important throughout large parts of the developing world, and susceptible to the techniques of plant breeding and selection for characteristics not necessarily situation-specific.

(f) A belief that the most appropriate immediate role for most emerging national systems in the proposed research agenda of the new strategy during at least the first decade would be in plant nursery networking and plant breeding. In time, the international centers would either 'work themselves out of a job' and be absorbed into the host national systems, or move towards specializing in more fundamental regional roles in training and research.

On the basis of these propositions the Ford and Rockefeller Foundations set about establishing IRRI. Shortly thereafter the idea that a network of international centers would be needed was accepted by decision makers in both

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foundations. At the time IRRI started operations CIMMYT, CIAT and IITA were already at least conceptually on the drawing board, being mentioned in correspondence relating to future planning. The two foundations and the original staff of these four centers recognized that they were embarking on a strategy for agricultural development that did not sit comfortably with that supported and pursued previously. Others had committed themselves to a strategy based on agricultural extension services, village leadership programs and broadly based community development, including rural credit and rural infrastucture. These services were recognized as necessary for agricultural development, but not sufficient. Missing was the research from which genuinely improved technology would be forthcoming. It was the latter void that the international agricultural research centers were designed to occupy, as complements to, and institutions that would help to strengthen, national agricultural research activities.

IRRI was initiated in 1959 as a completely new international effort to focus on the problem of how to achieve high yields of rice in the tropics. The Rockefeller Foundation made IRRI's first senior researchers members of its field staff, and the Ford Foundation made substantial grants to construct IRRI's buildings and to provide facilities. By early 1962 it ws operating. Later, members of the staff were employed directly by IRRI.

CIMMYT was established by an agreement between the Rockefeller Foundation and the Mexican government in October 1963. It absorbed some of the staff and facilities and much of the research base of the Mexican Agricultural Program

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of the Rockefeller Foundation, which had been operating since 1944. CIAT was formed in a somewhat similar way by agreement between the Rockefeller Foundation and the Colombian government in November 1967. IITA, like IRRI, was a new initiative and, in fact, took some time to become operational after it was established by a Nigerian governmental decree in July 1967 because of the civil war which erupted out in Nigeria after the decision to locate the center there had been made.

CIP had been created under Peruvian law in 1970 and was in the early stages of operating when the CGIAR was formed in 1971. Two years later the CGIAR agreeded to support CIP. ICRISAT was established and began operating under CGIAR sponsorship in 1972, ILRAD in 1973 and ILCA in 1975. The IBPGR was launched in 1975. ICARDA was developed in 1976, to a limited extent carrying on the work of the arid lands agricultural development program earlier sponsored by the Ford Foundation. IFPRI began operations in the same year, but it did so outside the CGIAR system, with support from several donors who were interested in seeing such a center. It was not until 1979 that IFPRI joined the system. ISNAR was established in 1980, specifically to help to develop national agricultural research programs. In 1971 the CGIAR began supporting part of the research activities of WARDA.

2.2 Diversity and Focus

2.2.1 The range of activities

The first two centers, IRRI and CIMMYT, had relatively straightforward objectives: to produce rice, maize and wheat plants that would yield well in the tropics where traditional varieties could not, regardless of how favorable the conditions. Other centers have faced more challenging problems because they have the more complex task of developing improved technology for ecological regions, not simply improving single crops.

The great diversity among centers arises to some extent from differences among the commodities, nations and geographic areas that each serves. Seeds of rice and wheat are easily and safely moved from one country to another, while potatoes and cassava have usually been propagated by root or tuber cuttings that are more difficult to ship, and transfer involves greater risk of transmitting some diseases. It is not surprising, therefore, that widescale testing of new varieties played a significant early role in the strategy of IRRI and CIMMYT while they have a somewhat smaller role at CIP, IITA and CIAT. The latter had first to give research attention to methods of vegetative propagation that could reduce the phytosanitary risks.

The CGIAR centers are thought of by some as consisting of a set of institutes like CIMMYT or IRRI focusing on one or two crops. Of the thirteen centers only eight, however, are primarily devoted to plant breeding research

designed to improve crop yield potential, and all but three of those centers carry out plant breeding work on more than one crop. Four centers have mandates relating to identified ecological regions and nine have some variant of a farming systems research program. Two centers are exclusively devoted to livestock research primarily designed to benefit African farmers (ILCA and ILRAD), and two others have major research programs aimed at improving pastures or forage crops on which livestock depend (CIAT and ICARDA). One center was created by the governments of some 15 African nations as a development agency and has since expanded its program to include research programs supported by the CGIAR (WARDA). One crop oriented center has no laboratories or fields but is concerned solely with facilitating the collection, conservation and preservation of plant genetic resources (IBPGR). Two centers are not biological research organizations at all, but rather provide advice and research analyses, especially to governments of developing countries, on how to build agricultural research systems (ISNAR), and on agricultural policies (IFPRI).

Within this diversity, it is clear that the primary activity of the CGIAR centers is to conduct agricultural research for the purpose of developing technologies leading to increased food production. Development is seen by the CGIAR as the ultimate purpose of support for international agricultural research. It is also clear that, within the system, efforts are being concentrated on research related to food crops, while at the same time it is recognized that there are other important ecological, economic and social factors related to technological development.

The need to strengthen national agricultural research capabilities is also explicitly recognized as a goal and function of the centers. This is ISNAR's central purpose, but other centers contribute importantly. In order to transmit findings effectively and to help to build national capacities, the centers sponsor workshops and conferences, carry out training programs and encourage their professional staff to interact on a personal basis with national researchers. This means that, in addition to their individual research activities, many center research personnel travel extensively in partner countries and teach in center-run training programs.

2.2.2 Similarities among centers

Despite obvious differences, a number of similarities can be identified across the centers: they are problem-oriented and hence results-oriented; they are international in outlook and staffing, they are relatively independent of government bureaucracies; they link with other research organizations (in their host and other countries) having similar objectives; they maintain high standards of professional performance.

Multidisciplinary - Problem Focused. The focus of each center on problems that appear to require a technological or institutional solution is one common feature. This problem focus was a somewhat novel basis for agricultural research institutions when the centers were formed. In most industrial countries, agricultural research institutions follow the organizational pattern of universities where disciplines form the institutional groupings of scientists. The wheat research in Mexico was addressed to developing high

high yielding, widely adaptable wheat varieties. IRRI was created in the hope of being able to break the ceiling that kept yields of tropical rice substantially below those achieved in temperate areas. Each of these centers were also focused on increasing productivity of a food commodity or ecological area for which increased production was considered critical to rapid development. This problem-solving orientation has resulted in multidisciplinary research programs in most centers, but this organizational mode comes from the orientation rather than from a new orthodoxy committed to overthrowing disciplinary organization *per se*.

International. The centers are international in several respects. They are staffed by research workers recruited from "around the globe". In most cases, nationals of the host country fill some of the senior posts, nationals of industrial countries make up about half the senior staff, and nationals from other developing countries make up the rest of the senior staff (Table 2.1). At centers located in countries with strong national programs, a number of nationally recruited scientists are also employed. Support staff are usually hired from the host country. Governing Boards likewise are constituted from people of donor countries and from countries where the work of a center is important. Board members each serve in their individual capacities except in the case of WARDA where the Governing Council is composed of officials designated by the member countries.

The programs of the centers are also widely spread among countries. The 13 centers are each located in a different country, ten of them in the developing world. In 1984 the centers stationed about 30 percent of their 800

Table 2.1 Nationalities of CGIAR center senior internationally recruited staff, percentage

	Percentage who are citizens of countries in					
Center	Asia	Africa	Latin America	N. Africa M. East	North America	Europe Japan Oceania
CIAT	6	1	40	0	27	25
CIMMYT	10	3	22	4	35	27
CIP	8	1	35	0	23	32
IBPGR	13	7	7	0	13	60
ICARDA	20	3	4	28	17	28
ICRISAT	25	10	1	1	34	29
IFPRI	39	3	3	3	32	19
IITA	28	26	4	3	21	17
ILCA	6	21	0	4	8	62
ILRAD	0	10	0	0	30	60
IRRI	34	0	2	0	38	27
ISNAR	6	6	19	3	29	35
WARDA	5	91	0	0	2	2
ALL	18	14	11	4	25	28

research scientists in 36 countries other than their headquarters location, with a heavy concentration in Africa (Table 2.2). Many of the outposted staff are funded through special projects but, increasingly, the centers are also placing core-funded staff outside their headquarters.

Independent. The centers are independent in their operations. The board, management and staff of each center determine its own program directions; no external organization has control. The Technical Advisory Committee (TAC) is the primary outside body that periodically examines the programs of the centers. This committee of 13 distinguished research leaders advises on research priorities, but does not have a controlling function. The CGIAR can, of course, influence program direction through its own comments on the programs of centers, and individual donors can influence programs through the provision of grants for particular activities. These are fairly general levels of influence, however, and the determination of research activities is the responsibility of each center. Since centers are also independent of the governments of the countries in which they are located (except in their normal civil responsibilities), they are relatively free from the bureaucratic delays that seem to be a part of all government and other large institutions, in industrial as well as developing countries. Although the Ford and Rockefeller Foundations were instrumental in initiating several of the centers and several of the centers' boards have members from among the officers of the Foundations, they no longer retain control of any center.

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Table 2.2 Numbers of CGIAR center staff posted outside their center's host country, including staff on special projects, 1984

Center	Number of staff posted						
		Outside host country in					
	In host country	Asia	N. Africa, Middle East	Latin America	West Africa	E & S Africa	Total
CIAT	50	1		11		3	65
CIMMYT[a]	62	12	2	9	5	6	96
CIP[b]	47	6	4	2		3	62
IBPGR	7	4	2	1	1	1	16
ICARDA	57		4				61
ICRISAT	48	1	2	2	20	7	80
IFPRI	28	2			1		31[c]
IITA[d]	73	1		3	27	2	106
ILCA	34				11	14	59
ILRAD	30						30
IRRI	80	12	3	1	1	2	99
ISNAR	26			1			27
WARDA[e]	34				34		68
Subtotal	576[f]	39	17	30	100	38	
All centers in region		128	42	159	107	55	
TOTALS[g]		169	59	189	207	93	800

a CIMMYT expects to have 15 staff members in Africa by the end of 1985.
b CIP expect to have 25 staff members in Africa by the end of 1985.
c Of the 31 IFPRI staff in 1984, only 17 were supported by core budget.
d 1983 data are shown; IITA expect to have 68 staff members in Africa outside their Nigerian headquarters by the end of 1985.
e 1983 data shown.
f Includes 63 IBPGR, IFPRI and ISNAR staff in host country not allocated to regional totals.
g Scientists were located in 38 countries without CGIAR centers; all centers developing countries had members of other centers posted with them.

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Excellence. The founders of the first centers intended that they be centers of excellence in research and training. To that end they recruited the best qualified professional staff and provided them with excellent facilities and supplies necessary to carry out first-rate applied research. At the same time, it was made clear that excellence and relevant research applied to solving food production problems were to be pursued. The concept of being centers of excellence in applied research has continued as central to the CGIAR.

Linkages. In order to fulfill their international mandates, each of the centers maintains extensive links, both formal and informal, to other agricultural researchers with common interests. Formal links are forged through the operation of research networks in which researchers in several countries, all of whom are working on similar problems, meet periodically, review research findings and plan future work. A center may provide information, seeds or other research materials to members of the network who, in turn, share their results and help to decide on research priorities for the network. Conferences and workshops where researchers from several countries can come together to discuss their work and exchange experiences are important in developing good working relationships that keep formal networks solid and functional. Informal links are established by center scientists visiting the experiment stations of national programs and interacting with their colleagues there. Links between the centers and national research institutions are also maintained through conferences, professional associations, contract research and professional literature. Where two or more centers have over-

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lapping research interests there is a flow of people and paper between them that maintains close ties.

The centers are only a small part of the emerging global system for the production of new agricultural technology. Their presence has catalyzed the growth of national agricultural research programs in the developing countries (chapter 10). At the same time, extension systems to deliver research results to farmers are slowly being strengthened. National researchers and international centers alike draw on the basic research and disciplinary knowledge of advanced institutions throughout the world as the knowledge base upon which improved technology is founded. Such institutions play an important role in the education of most researchers, especially at the doctoral level, for the developing countries and for the centers.

2.2.3 Concentration on applied research

Clearly, the parts of this emerging global system for agricultural research each have particular capabilities and advantages to carry out a part of the task that is necessary. The centers concentrate on applied research where there is a comparative advantage arising from their capacity to move people and materials internationally, but they also engage in some strategic research.

Because these categories of research are often understood to have different meanings by different people, the following definitions, enunciated by the Second Review of the CGIAR, are generally followed in this report:

(a) basic research — designed to generate new understanding (e.g., how the partitioning of assimilates is influenced by plant height);

(b) strategic research — designed for the solution of specific research problems (e.g., a technique for detecting dwarfing genes in wheat seedlings);

(c) applied research — designed to create new technology (e.g., breeding new varieties of dwarf wheat that can respond to high levels of nitrogen without lodging);

(d) adaptive research — designed to adjust technology to the specific needs of a particular set of environmental conditions (e.g., incorporating dwarf wheats into farming systems in a designated, perhaps unirrigated area).

Scientists are as unhappy as non-scientists at being labelled, so there is little agreement among the centers as to how activities should be categorized. This, however, has not deterred the authors of this report from attempting such a categorization, shown in Table 2.3.

Research at the centers spans the range of the four types mentioned, but the bulk of activities are in applied research. Crop improvement, defined to include plant breeding and the complementary research in plant pathology, virology and entomology, is the main category of work of senior staff in the centers. The crop-oriented centers devote 25 to 40 percent of their senior staff resources to these applied crop improvement activities and genetic resource conservation.

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Table 2.3 Approximate proportion (percent) by center of senior internationally recruited staff members with primary responsibilities in four major categories of activities, 1984

Center	Strategic research	Crop-improvement applied research	Other applied research	Training, research support and administration
CIAT	13	49	23	13
CIP	15	30	28	27
CIMMYT	14	45	24	17
IBPGR		83		17
ICARDA	11	33	10	45
IFPRI			93	7
ICRISAT	13	40	21	26
IITA	11	34	27	27
ILCA	6		59	34
ILRAD	83		6	11
IRRI	10	26	35	28
ISNAR			16	84
WARDA		10	34	56

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Other applied research activities, defined to include agronomy, economics, engineering, farming systems and animal nutrition, make up 15 to 30 percent of the senior staff resources of eight centers. IFPRI research is included in this category in the table, as is ISNAR's research. However, the bulk of ISNAR's staff are committed to activities that are more directly related to the second general objective of the centers -- that of enhancing developing country capacity for research. These staff members are included in the right-most column of the table.

Training and other activities aimed at improving the capacity of developing country researchers are grouped together with research support and administration because it is impossible to separate them. A significant part of the staff time of the senior administrators is spent arranging to provide center products to national researchers, and most centers also have administrative or liaison staff designated to work with national programs. Training activities are devoted to this purpose, and research support activities like library work and communications are also significant contributors. The proportion of staff time devoted to these activities ranges from about 15 to 30 percent in most of the centers.

Virtually none of the centers' efforts are devoted to basic research conducted purely to build up knowledge with no clear idea of how that might be used to enhance food production. A modest proportion of most centers' activities is devoted to strategic research, where the purpose is the solution of specific research problems, but the product of which is far from being an

immediately applicable technology. The bulk of ILRAD's researchers work at such activities, addressing the problems that need to be solved in order to generate technologies to control trypanosomiasis and theileriosis. The other centers use from 10 to 15 percent of their staff resources on strategic research.

2.3 Commodity and Ecology Objectives

The CGIAR uses the term "mandate" to define the area of responsibilities of the centers but, as one careful observer of the system has noted, the meaning of the word is somewhat different from its use within the CGIAR.

> "Stricto sensu a mandate is something handed down by a superior authority, which monitors its implementation, and the terms of a mandate both authorize and limit the discharge of specified functions. It carries the connotation of the entrustment of a public duty in conditions which cannot be varied save by reference to the issuing authority. It does not imply exclusivity of entrustment."

> "I believe that we could avoid some of the inappropriate overtones of the word if we discussed the roles of the centers and their inter-relationships in terms of "Objectives and Purposes" and in an evolutionary and complementary context. We should also look at problems conjointly as features of a system,

or at least of an agglomeration (O.E.D. a collection of things rudely thrown together (1831))."

"The objectives and purposes of each center are stated in the charters or constitutions establishing the institution. These documents have been consecrated successively over the past twenty-odd years and little conscious care was taken to ensure consistency. The later documents in the series have been more tightly drawn. Successive programs of work are established within the ambit of these statements and I am not aware of any instance where the mandate has proved an impediment. In the nature of things, perceived priorities and resource constraints dictate that programs of work are selective within the mandate" (Mathieson 1984).

The successive programs of work that have evolved at the centers have led to recognition of two types of mandates: the formal and the operational. Only the formal can be found in the written documents of the centers but the TAC and its external review panels have recognized the distinctions and provided a guide to them (Table 2.4).

CIAT and IITA have the broadest formal mandates, CIAT's covering food crops and animal products of the tropical lowlands with emphasis in Latin America and IITA's covering tropical food crops and alternatives to shifting

Table 2.4. Formal and Operational Mandates of 10 Biological Research Centers

Centers	Formal Mandates: Commodity/Activity	Formal Mandates: Region/Agro-ecological zone	Operational Mandates: Commodity/Activity	Operational Mandates: Region/Agro-ecological zone
CIAT	Food crops Animal products	Tropical lowland with emphasis in Latin American	Phaseolus bean Cassava Rice Tropical pastures, lowland tropics	World World Latin America Latin America
CIMMYT	Wheat Maize Sorghum Rice Other food crops	World World Undefined Undefined Undefined	Wheat Maize Triticale Barley	World World World Latin America
CIP	Potato Other root crops	World World	Potato	World
ICARDA	Dry subtropical or temperate climate primarily Near East, North Africa and Mediterranean Barley Lentils Broad beans Other crops Wheat Chickpe	 World World World World N. Africa/N. East N. Africa/N. East	Same as formal with concentration on non-irrigated agriculture Farming systems	 Dry areas of region
ICRISAT	Sorghum Millet Pigeonpea Chickpea Groundnut low rainfall unirrig. seasonally dry and semiarid tropics	World World World World World 	Sorghum Millet Pigeonpea Chickpea Groundnut Farming systems semi-arid tropics	World World World World World Asia, Africa
IITA	Farming systems and selected food crops	World	Rice Maize Cassava Cocoyam Soybean Plantains Sweet potato Yam Cowpea Farming systems humid and subhumid tropics	Africa Africa Africa Africa Africa Africa World World World Africa
ILCA	Livestock production systems in Africa	Africa	Livestock production systems in Africa	Africa
ILRAD	Trypanosomiasis Theileriosis Other diseases		Trypanosomiasis Theileriosis	
IRRI	Rice	World with emphasis on Asia	Rice	World with emphasis on Asia
WARDA	Rice	West Africa	Rice	West Africa

Source: TAC Priorities Paper, 1985 (slightly modified).

cultivation. CIAT has focused more sharply on four commodities, concentrating its work on two for Latin America. IITA continues research on eight or more crops, most focused on Africa. Both are conducting research that, if successful, would increase the productivity of land now being used at a low level of intensity. CIAT research would greatly increase the productivity of high acid pasture soils while IITA is striving to develop effective farming systems which would help maintain land productivity in the high rainfall tropics where the bush-fallow system is being forced into an ever shorter cycle by rapid population growth.

CIMMYT's formal mandate is considerably broader than its operational interpretation, the former including sorghum, rice and "other food crops" in addition to wheat and maize. Operationally CIMMYT includes barley and triticale but leaves rice to other centers and provides ICRISAT with logistic support for its Latin American sorghum research.

There is much closer correspondence between the formal and operational mandates of each of the other centers, respectively, for varying degrees of emphasis on different aspects implemented in their operational mandates.

2.3.1 Food production research

When each center was established, a major concern of the individuals charged with establishing it (different individuals in each case) was to ensure that the center was focused on some aspect of the principal food production problems that appeared to need an international research effort. Some centers were deliberately given a world-wide, or primary crop responsibility.

A number were given ecological or regional foci with restricted responsibility for crops for which another center had a primary responsibility.

The result is a system of research centers conducting research on most of the main food sources of people in the developing world (Table 2.5). One or more centers is conducting crop improvement research on each of the cereals which, as a group, contribute 60 percent of the energy and 55 percent of the protein consumed by people in the developing countries. Roots and tubers are particularly important in Africa and certain places in Asia. CGIAR centers are conducting research on all the roots and tubers that provide a significant proportion of food on a global basis. Pulses or food legumes are especially significant for their contribution to protein consumption, providing eight percent on average, but a much higher proportion among rural low-income people in Africa, Asia and the Middle East. Four centers are working on pulse crops. The two livestock institutes are conducting research that should contribute to greater productivity of cattle, sheep and goats everywhere, but livestock problems in Africa are receiving principal attention.

Together, the foods that contribute 75 percent of the energy (1776 kcal/day) and 74 percent of the protein (21.4 gm/day) of people in all developing countries are "covered" by the CGIAR centers. It is recognized that the point of departure here is how things are rather than the more challenging alternative of how they might be with changing tastes and incomes. The major food commodities not being directly studied at the centers are sugar, pork, poultry, eggs, fish, seafood, alcoholic beverages, vegetables and oilseeds.

Table 2.5 Principal food sources in the developing countries, their daily energy and protein contribution and CGIAR centers conducting research on each.

Commodity	Energy kcal/day	Energy %	Protein gm/day	Protein %	CGIAR centers responsible[a]
Cereals	1412	60.1	15.8	54.5	
Wheat	411	17.5	5.2	17.9	CIMMYT, ICARDA(R)
Rice	688	29.3	7.3	25.2	IRRI, IITA(R), CIAT(R), WARDA(R)
Maize	178	7.6	1.6	5.5	CIMMYT, IITA(R)
Millet	54	2.3	.5	1.7	ICRISAT
Sorghum	61	2.6	.6	2.1	ICRISAT
Barley	19	0.8	.2	0.7	ICARDA, CIMMYT(R)
Roots, tubers, etc.	213	9.1	.8	2.8	
Cassava	61	2.6	- [b]	-	CIAT, IITA(R)
Potato [c]	33	1.4	.5	1.7	CIP
Sweet potato [c]	73	2.1	.4	1.4	IITA
Yam	12	0.5	-	-	IITA
Cocoyam	2	0.1	-	-	IITA
Others	2	0.1	-	-	
Plantain	24	1.0	-	-	IITA
Pulses	87	3.7	2.3	7.9	
Chickpea	14	0.6	.4	1.4	ICRISAT, ICARDA(R)
Cowpea	2	0.1	-	-	IITA
Faba bean	9	0.4	.3	1.0	ICARDA
Field bean	26	1.1	.7	2.4	CIAT
Groundnut	14	0.6	.4	1.4	ICRISAT
Lentil	2	0.1	-	-	ICARDA
Pigeonpea	5	0.2	-	-	ICRISAT
Soybean	14	0.6	.5	1.7	IITA
Livestock and products	146	6.2	5.5	19.0	
Beef and buffalo	23	1.0	1.4	4.8	ILCA, ILRAD
Sheep and goats	2	0.1	-	-	ILCA, ILRAD
Milk	40	1.7	1.2	4.1	ILCA, ILRAD
Pork, poultry, eggs	80	3.4	3.0	10.3	none
Vegetables	35	1.5	.9	2.1	none
Oilseeds	68	2.9	-	-	
Coconut	94	4.0	-	-	none
Oilpalm	16	0.7	-	-	none
Other oilseeds	42	1.8	-	-	
Sugars and honey	150	6.4	.1	0.3	none
Fish and seafood	15	0.6	2.5	8.6	none
Alcoholic beverages	30	1.3	.2	0.7	none
Other foods [d]	193	8.2	.9	2.1	
Total	2349		29.0		

a (R) indicates a regional responsibility.
b Less than .1 gm/day.
c Adjusted to reflect latest information showing 50 million tons of potato and 95.7 million tons of sweet potato production annually in China.Mainly
d fruit, nuts, animal oils and fats, stimulants and spices.

Source: TAC 1985 and FAO 1984.

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2.3.2 Regionally focused research

A number of centers define a significant proportion of their activities primarily in terms of particular ecological areas: ICRISAT in the semi-arid tropics, ICARDA in the dry areas of the Middle East and North Africa, CIAT's pasture program in the acid, infertile soils of tropical America, ILCA in the livestock producing areas of Sub-Saharan Africa, IITA in the humid and sub-humid tropics of Africa, WARDA on rice in its member nations. Some other centers that have farming systems programs have distinct ecological foci such as IRRI's on rice-based areas of Asia.

The centers have evolved a number of ways of working in locations outside their headquarters that permit them to conduct applied research in ecological regions outside the countries in which they are located. Some centers have agreements with national authorities under which center staff are stationed as regional scientists, usually with some facilities supplied by the country. Other centers have liaison scientists stationed outside their host country. A substantial number of center researchers work directly with national researchers under contract arrangements in which a donor provides special project funds for the purpose. Collectively termed "outposted staff", their functions range from administrative tasks such as helping to arrange for nationals to participate in centers' training programs and advising on the operations of national research programs, to research such as making crosses and selecting promising varieties. In each case, the national program in which the scientist is located has the opportunity for a much closer relationship with the center than it would have otherwise.

Table 2.2 shows the number of internationally recruited center staff located by region in 1984. Center staff were stationed in 36 countries without a CGIAR center in 1984, 20 of those countries being in Africa. The number and location suggest that the centers, donors and countries all are aware of those places where the needs for such staff are greatest: 100 staff members were stationed in W. Africa, and 38 in E. and S. Africa. This amounted to 43 and 16 percent, respectively, of the total outposted staff in 1984. On the other hand, Latin America, which has relatively well developed national capacities, had only 13 percent of the outposted staff.

Staff postings give some idea of the allocation of research effort. Budgetary data can supplement this picture. It is relatively easy to identify some expenditures with specific geographic locations, where the operational mandate is identified with a region as in Table 2.4, but allocating the core budgets of some expenditures is more difficult, and in some regards is impossible because much research has a potential payoff in several areas. In such cases core expenditures were allocated in approximate proportion to the relative area of the crop in each region. Recognizing that the best efforts can give only an approximate indication of the geographic distribution of research efforts, the CGIAR Secretariat has developed such an allocation (Table 2.6).

The interrelated nature of commodity and region in research is clearly illustrated in Table 2.6. There is naturally a concentration of research activities in those regions where a crop contributes a high proportion of consumption. Thus, 40 percent of rice research investments are in Asia, 52 percent of research investment on roots and tubers are in Africa and 63 percent of research on pulses is carried out in semi-arid W. Africa, India, N. Africa and the Middle East.

Table 2.6 Approximate annual allocation of CGIAR centers expenditures (mil 1983$) to major activities and to continental regions expected to derive the principal impact of such activities (1984-86 average, using budgeted levels for 1985 and 1986).

Program area	Total	Africa	Asia	Latin America	Middle East North Africa
Crop improvement					
Cereals[a]	33.0	8.8	15.6	5.3	3.3
Roots and tubers[b]	8.2	2.9	0.7	4.1	0.5
Food legumes[c]	10.1	2.4	2.5	2.7	2.5
Livestock					
Production systems	11.6	6.7	0	3.4	1.5
Disease control	4.1	4.1	0	0	0
Food policy	2.4	1.0	0.8	0.3	0.3
Farming systems	7.7	3.9	1.7	0	2.1
Genetic resources Conservation	4.2	0.9	1.1	11.0	1.2
Research support	21.1	9.4	2.9	6.0	2.8
Strengthening national capacities					
Training and conferences	13.8	4.7	4.8	3.1	1.2
Information and communications	9.8	4.0	2.2	2.3	1.3
Technical assistance	2.6	0.5	0.7	0.5	0.9
Research management					
Administration and management	20.4	7.3	4.9	4.6	3.6
General operations	23.4	10.8	5.3	4.4	2.9
Total operations	172.4	67.4	43.2	37.7	24.1

a Rice - 41%, wheat 18%, maize 14%, sorghum 6%, millet 7%, other 14%.
b Cassava 23%, potatoes 48%, others 29%.
c Field beans 30%, groundnut 15%, other food legumes 55%.

Source: CGIAR Secretariat

Allocations on the basis of relative crop area, however, may not adequately reflect the reality of intended targets in Africa, especially for core expenditures on maize, sorghum and millets where the lead center is in another region. Notwithstanding the initiatives of ICRISAT in recent years in west, southern and eastern Africa, attention to sorghum and millet improvement in Africa may be inadequate.

2.3.3 Linkage of center and national researchers

In addition to having staff located in a number of countries, an extensive set of links has developed between centers and agricultural researchers in both developing and industrial countries. Training is one basis for the most important kind of links -- personal contacts. Other important links are formed by research networks, flows of information, and international meetings and conferences.

Perhaps the strongest links are formed between professor or research guide and student, especially at the graduate level where students establish lasting personal and professional contacts. Students emulate their teachers while professors are influenced by their students' work. Often a student continues a line of research initiated during graduate thesis work at a center, providing a natural link between centers, universities and developing country research programs. Many staff members of centers have been trained in

the same industrial country universities and relate to their universities in much the same manner as research workers from national programs.

The centers do not award graduate degrees but they do provide opportunities for students to conduct dissertation research. In addition, the centers provide opportunities for individual technical training and short-term formal courses (Table 2.7). Currently, the centers provided opportunities for over 350 students studying for master's and Ph.D. degrees to conduct thesis research in association with center staff. Because the university adviser is involved and interested in the research, a three-way link is formed between student, adviser, and center staff members.

Individualized research training provides opportunities for researchers from national programs to carry out research in association with center scientists in a one-to-one relationship, sometimes as post-doctoral fellows for one or two years and sometimes for shorter periods. Formal courses at centers range in length from 2 weeks to 6 months and usually focus on training in specific technical research skills. Even though short-term, these provide important opportunities for establishing links that permit the exchange of ideas, publications, research techniques and information between a center and national researchers.

Research networks take a wide range of forms. Typically, participants meet to plan work, discuss results and draw conclusions. The most common type of network may be those for testing genetic materials that are operating for

Table 2.7. Approximate current number of participants in four major types of training programs at centers.

Center	Number of participants in			
	Individual research training	Degree related[a]	Group courses	Post doctoral programs
CIAT	135	25	90	15
CIMMYT	70	5	130	15
CIP	50	10	540[b]	
IBPGR	5	10	130	
ICARDA	10	10	40	5
ICRISAT	15	30	90	20
IFPRI	5			10
IITA	25	65	500	10
ILCA	15		110	5
ILRAD		15	25	10
IRRI	100	150	240	20
ISNAR			180	
WARDA		20	120	
Totals	430	340	2275	110

a Scholars who are taking advanced degrees at universities and conducting degree research at the center specified, except in the case of WARDA which shows number taking advanced training abroad.

b Includes participants attending courses conducted by CIP regional staff outside CIP headquarters.

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most center commodities, including wheat, maize, rice, beans, cassava, cowpeas, soybeans, yams, pearl millet, and sorghum (see chapters 6 and 12 and the listing of Appendix 2.1 at the end of this Chapter). They provide national researchers with samples of varieties or lines that have been found useful in other countries and in centers. In most cases, anyone in the network can suggest materials to be included. People in the network participate to the extent that they individually feel is best. Naturally, the most complete information is generated when all members of the networks participate fully.

In addition to germplasm exchanges, the centers have initiated a number of networks focused on specific research problems (see Table 10.4). Examples include the regional research networks for potatoes that are functioning in the Andean countries, Central Africa, Central America and the Caribbean and in S. Asia which CIP has been instrumental in establishing. A network on soil fertility and fertilizer evaluation for rice is coordinated by IRRI; the African Association for Biological Nitrogen Fixation is coordinated by IITA. The IBPGR coordinates an extensive network of researchers concerned with genetic collection work through its joint program planning and by providing common procedures, nomenclature and standards.

Another kind of linkage is provided by networks concentrating on training, such as the E. African economics network and the Asian farm machinery network. These networks are not concerned with research planning and coordiation but are important for information dissemination rather than research coordination. The trypanotolerance network and the African research network on agricultural byproducts also facilitate the flow of information.

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Information is a priority of the CGIAR system. In recent years, center information and documentation services have been allocated an average of 5.4 percent of the System's cumulative core budget. While programs vary in terms of size and sophistication, each center produces publications aimed principally at researchers and policymakers in national and regional programs. Other important audiences include extension program personnel, students of agriculture and donors. To date, an estimated 10,000 titles have been produced on subjects covering twelve commodities and some two dozen scientific disciplines. All avialable CGIAR publications—an estimated 5,000 titles—are listed in the catalog "Publications on International Agricultural Research and Development" (IRRI and GTZ 1984).

The centers' principal publications are their annual reports and research highlights, both of which serve the double function of communicating research results to national programs and assisting policymakers and donors in evaluating CGIAR research. Formats range from 400-page omnibus reports to comparatively short publications that cover a single commodity or program.

The reports are augmented by specialized publications that concentrate on a spceific discipline or geographical location or that expand on a highly specialized topic. Included are monographs based on completed research projects, bibliographies derived from center data bases, and proceedings of international workshops and symposia.

The centers are also publishers of numerous agricultural newsletters. About 30 newsletter series are published annually on topics relating to general research, crop testing networks, genetic resources and specialized information dissemination services. Center newsletters also serve as outlets for research generated in national programs, and thus providing collaborating scientists with an opportunity for exchange of information through a worldwide food crop research network. Most centers have library services that send copies of papers to national researchers upon request. ILCA and IITA have abstracting services and computerized library services that identify current research papers in the fields of specialization of collaborating researchers. Such selective dissemination of information permits them economically to inform a large number of researchers about the existence of publications of potential interest.

The working language of the centers is English; however, several centers produce publications in French, Spanish and local languages. To accelerate the translation of English-language texts, several centers are emphasizing copublication, a technique in which an original text is produced in such a way that it can be easily translated and reprinted in a second language. The centers offer copublication-acceptable texts to national programs free of charge, and in several instances have assisted cooperators by printing translated versions at cost.

Center publications are distributed in approximately 160 countries worldwide. While distribution policies vary, the centers' common objective is to ensure that research results reach their intended audience quickly, efficiently and at minimum cost to the receiver. Although the majority of the centers' 60,000 subscribers are served by mail, center publications are distributed to remote locations through special couriers, international airline distribution systems or by center outreach programs. More than 20 percent of CGIAR information budgets are spent on distribution.

The centers' 13 publication units are staffed by editors and writers. Senior staff are recruited internationally, but are supported by local artists and technicians, many of whom received their initial training at the centers and have since joined the private sector. Most programs have in-house printing and binding capabilities, as well as access to computers, word processors and phototypesetters.

In recent years, national programs have called upon the center to provide training in various aspects of publication production. While center information programs were not designed for this purpose, the need for trained editors and technicians at the national level has prompted several centers to initiate training programs on a limited scale. The programs emphasize "hands-on" training for editors, printers, artists, and photographers. Funding is provided either by donors or, in some instances, from the centers' core budgets.

2.4 Size and Growth of the CGIAR

In 1971, the first four CGIAR centers had a total budget of $17.8 million. By 1980, when 13 centers were operating, the first oil crisis had sent the world rate of inflation soaring so that the total budget for three times as many centers was ten times as large, totalling about $120 million. The budget for the centers in 1984, after the second oil price shock, was about $175 million.

The CGIAR system grew rapidly during its early years, both in terms of number of centers and budget. It is useful to recall that the period since 1970 was one of rapid growth in development assistance budgets in general, only part of which was a reflection of inflation. Official development assistance grew fourfold in current dollars, from $8.2 billion in 1970 to $34.2 billion in 1982, according to the statistics of the OECD. Over the same period, CGIAR expenditures increased roughly twice as fast, but in constant dollar terms, the increases were much slower.

Official development assistance from the OECD countries, the OPEC countries and the E. European countries increased from $21.3 billion in 1970 to $34.8 billion in 1982, in constant dollars (Table 2.8). Of that, $7.6 billion was channeled through multilateral agencies such as the World Bank, UNDP, FAO and the CGIAR. A breakdown of OECD assistance by sector shows that, in 1982, 15 percent of the total for technical assistance was allocated to agricultural assistance. Some 28 percent of the assistance from the World Bank, the

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regional development banks and USAID went to agriculture in 1982-83, a total of $5.6 billion per year (Sanford 1984, p CRS-259). The CGIAR's expenditures over 1982-83 averaged $144 million, which amounted to about 2.5 percent of this $5.6 billion.

Thus, the CGIAR's growth rate has been faster than other development assistance for agriculture but, even in recent years, it has formed a very small fraction of the total. Figure 2.1 gives a visual impression of how CGIAR expenditures on various research programs have changed over time. Prior to 1974, cereals dominated. Livestock grew substantially in importance between 1974 and 1978 when ILCA and ILRAD were being established. After 1979, when IBPGR, IFPRI and ISNAR were being established, the "multi-commodity system research" category led the expansion.

Figure 2.2 and Appendix Table 2.2 show the pattern of support for the CGIAR over time. In 1972, the initial year of operation, 16 donors provided $20 million through the CGIAR. Since then the number of donors has exceeded 40, with about 35 contributing in each year recently. Initially, the Ford and Rockefeller Foundations, dominated, providing 46 percent of the total in the first year. By 1976 they contributed less than 10 percent of the total, with Canada, the Inter-American Development Bank, the United States and the World Bank each contributing over $5 million. By the 1980s, Australia, the EEC, the Federal Republic of Germany, IFAD, Italy, Japan, the United Kingdom and the UNDP were all contributing in excess of $5 million each.

Table 2.8. Global expenditures on official development assistance (ODA) to developing countries, national expenditures on agricultural research, and CGIAR expenditures

	1970	1980	1982
	(1981 billion $ constant)		
I. Official development assistance[a]	21,300	36,210	34,970
Bilateral	18,450	28,650	27,370
Multilateral	2,860	7,560	7,610
Grants by PVAs	2,220	2,240	2,360
II. ODA commitments by purpose			
Total[b]			32,070
Allocable by sector			16,680
of which tc			6,690
of which agriculture			1,000
Not allocable by sector			15,380
of which food aid			2,640
III. National agricultural research, world	5,340	7,390	n.a.
N. America, Oceania, W. Europe	2,400	3,210	n.a.
USSR and E. Europe	1,280	1,490	n.a.
Developing Countries	1,670	2,680	n.a.
IV. CGIAR expenditures	20	140	140

a From "DAC" countries (OECD) + OPEC + Socialist + Multilateral.
b "DAC" and multilateral.

Source: OECD Development Cooperation, (1983) and Judd, Boyce and Evenson. (1984)

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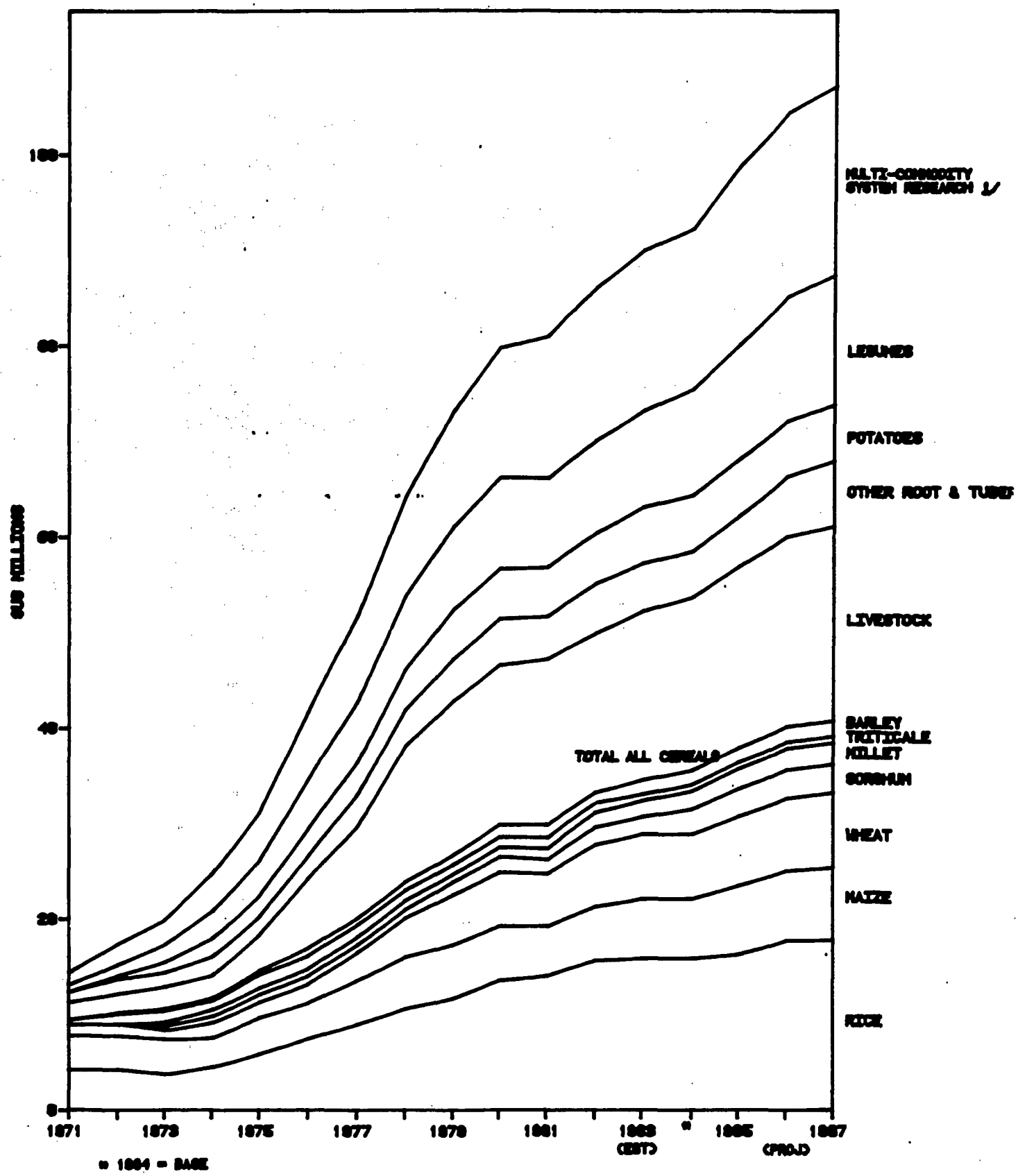
FIGURE 2.1

ANNUAL RESEARCH AND RESEARCH SUPPORT EXPENDITURES BY COMMODITY 1971-87
(IN TERMS OF CONSTANT 1983 DOLLARS)



* 1984 = BASE

1 FARMING SYSTEMS, FOOD POLICY, GENETIC RESOURCE CONSERVATION AND ASSISTANCE TO NATIONAL RESEARCH PROGRAMS.

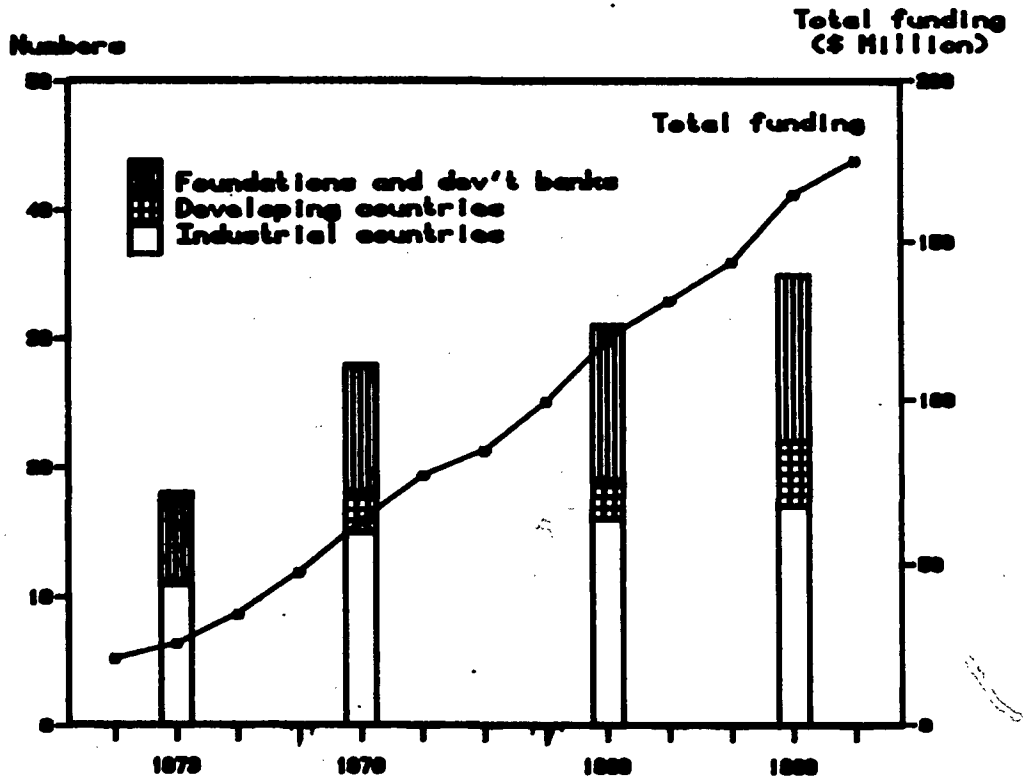
Nigeria, India, Mexico, the Philippines and China have become regular financial contributors to the system. Five other developing countries or developing country organizations have been occasional financial supporters. Thus, the CGIAR has growing financial support, with some of the primary beneficiaries providing modest amounts, and with a broad base of support among the major donor countries.

2.5 Coda

* The centers constitute a heterogenous group of institutions of varying ages and sizes, each with a different organization and operational objective. The diversity among centers arises to some extent from differences in the commodities, nations and geographic areas that each serves. Only eight are primarily devoted to plant breeding research designed to improve crop yield potential. Four centers have identified ecological regions in their mandates. Nine feature some variant of a farming systems research program.

* The problem focus of the centers has resulted in multidisciplinary research programs in most centers. The centers are international in several respects. Nationals of industrial countries make up about half the senior staff, and scientists from developing countries make up the rest of the senior staff. Governing Boards likewise are constituted from people of donor countries and of countries where the work of a center is important.

Figure 2.2
Number of donors to the CGIAR and total funding provided.



* The programs of the centers are widely spread among countries. In 1984 the centers stationed about 30 percent of their 800 research scientists in 36 countries other than their headquarters location, with a heavy concentration in Africa.

* Each center is independent in its operations. The Technical Advisory Committee periodically examines the programs of the centers, but does not have a controlling function. Centers are also independent of the governments of the countries in which they are located, and are relatively free from the bureaucratic delays that seem to be a part of many large and government institutions.

* The founders of the centers recruited well qualified professional staff and provided them with excellent facilities and supplies necessary to carry out first-rate scientific research relevant to solving food production problems.

* Formal links are forged through the operation of research networks in which a number of researchers in several countries working on similar problems meet periodically, review research findings and plan future work. Workshops are important in developing good working relationships that keep networks functional.

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* The centers are only a small part of the growing global system for the production of new agricultural technology. Most activities are in applied research. Crop improvement is the main category of work of senior staff in the centers. Other applied research activities, defined to include agronomy, economics, engineering, farming systems and animal nutrition, make up 15 to 30 percent of the senior staff resources of centers.

* Programs of work at the centers have led to recognition of two types of mandates: the formal and the operational. CIAT and IITA have the broadest formal mandates. CIMMYT's formal mandate is considerably broader than its operation interpretation. The formal and operational mandates of the other centers are, respectively, quite similar.

* One or more centers is conducting crop improvement research on each of the cereals which, as a group, contribute 60 percent of the calories and 55 percent of the protein consumed by people in the developing countries. The centers are conducting research on all the roots and tubers that provide any significant proportion of food on a global basis. Livestock problems in Africa are receiving principal attention. Together, the foods that contribute 75 percent of the calories and 74 percent of the protein of people in all developing countries are "covered" by the centers.

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* Some centers have agreements with national authorities under which center staff are stationed as regional scientists. Others have liaison scientists stationed outside their host country. Center staff were stationed in 36 countries without a center in 1984.

* Currently, the centers provide opportunities for nearly 350 students studying for masters and Ph.D. degrees to conduct thesis research in association with center staff. Over 2000 people attend formal courses at centers ranging in length from 2 weeks to 6 months, focused on training in specific technical research skills. Over 400 per year participate in individualized programs in addition to about 100 post-doctoral appointments annually.

* Research networks take a wide range of forms. In addition to germplasm exchanges, the centers have initiated a number of networks focused on specific research problems. Most centers have library services that concentrate on the world literature relevant to their respective manadates and partners needs. Upon request they send copies of papers to national researchers. Publications of sometimes centers may be the only relatively easily available scientific information in some national programs.

Appendix Table 2.1 Countries receiving germplasm through international testing programs, by commodity.

	Rice	Pearl Millet	Pigeon Pea	Chick Pea	1/Ground-nut	Potato	Sorghum	Tropical2/ Pastures	Maize	Wheat3/	Beans	Cassava
SOUTH ASIA												
Afghanistan									●	●		
Bangladesh	●			●	●	●			●	●	●	
Bhutan						●				●		
Burma	●			●	●		●		●	●	●	
India	●					●			●	●	●	
Mongolia												
Nepal	●		●			●	●		●	●		
Pakistan	●	●	●	●	●	●	●		●	●		
SriLanka	●					●	●		●	●		
EAST AND SOUTH EAST ASIA												
China	●				●	●	●	●		●	●	●
Indonesia	●		●	●	●	●	●	●	●	●	●	●
Korea (South)	●								●	●		
Malaysia	●		●		●		●	●	●			
Philippines	●		●	●	●	●	●	●	●	●	●	●
Singapore	●											
Taiwan	●					●				●		
Thailand	●		●	●	●	●	●	●	●	●		
Vietnam	●					●			●			
PACIFIC AND INDIAN OCEAN												
Fiji	●					●						
New Caledonia	●							●				
Papua-N.G.									●			
Samoa						●						
Solomon Islan	●											
Tahiti									●			
Vanuatu	●											
NORTH AFRICA AND MIDDLE EAST												
Algeria	●								●	●		
Cyprus						●				●		
Egypt	●			●	●		●		●	●		
Iran						●				●		
Iraq						●			●	●		
Israel	●					●				●		
Kuwait												
Lebanon										●		
Libya									●	●		
Morocco									●	●		
Qatar		●							●	●		
Saudia Arabia			●				●		●	●		
Syria				●					●	●		
Tunisia				●		●				●		
Turkey						●			●	●	●	
Yemen A.R.							●		●	●		
Yemen D.R.										●		
WEST AFRICA												
Angola						●			●	●		
Benin									●			

Appendix Table 2.1 Countries receiving germplasm through international testing programs, by commodity.

	Rice	Pearl Millet	Pigeon Pea	Chick Pea	1/Ground-nut	Potato	Sorghum	Tropical2/ Pastures	Maize	Wheat3/	Beans	Cassava
Burkina Faso	●	●					●		●	●		
Cameroon	●	●				●	●		●	●		
Cape Verde			●						●	●		
Congo									●	●		
Gabon									●			
Gambia	●						●	●	●		●	
Ghana							●		●		●	
Guinea	●								●			
Guinea-Bissau	●								●			
Ivory Coast	●			●	●				●	●		
Liberia	●					●			●			
Mali	●	●	●				●	●	●			
Mauritania	●	●										
Niger	●	●					●	●		●		
Nigeria	●	●	●				●	●	●	●		
Senegal	●	●			●	●	●	●	●	●		
Sierra Leone	●					●			●			
Togo	●					●			●			
Zaire	●	●				●	●	●	●	●		
EAST AND SOUTH AFRICA												
Botswana					●	●	●					
Burundi						●			●	●	●	
Central African R.									●			
Ethiopia			●	●		●	●	●		●	●	
Kenya	●		●			●	●	●	●	●		
Malagasy	●	●				●						
Malawi	●	●		●	●	●	●		●	●		
Mozambique						●	●		●	●		
Rwanda			●			●	●			●	●	
Somalia							●		●	●		
South Africa			●				●	●	●		●	
Sudan		●	●	●	●	●	●		●	●		
Swaziland						●			●	●		
Tanzania	●		●	●		●	●	●	●	●		
Uganda		●	●				●		●	●		
Zambia	●	●		●	●	●	●		●	●		
Zimbabwe		●			●		●		●	●	●	
CARRIBEAN AND CENTRAL AMERICA												
Bahamas									●			
Barbados						●			●			
Belize	●			●			●	●	●			
Costa Rica	●					●		●	●	●		
Cuba	●					●		●	●		●	
Dom. Rep.	●					●			●	●		
El Salvador	●						●	●	●			
Guatemala	●					●	●		●	●	●	
Haiti									●		●	
Honduras						●	●		●			●
Jamaica	●							●	●		●	
Mexico	●			●		●	●	●	●		●	●
Nicaragua	●						●	●	●		●	
Panama	●					●		●	●			●

Appendix Table 2.1 Countries receiving germplasm through international testing programs, by commodity.

	Rice	Pearl Millet	Pigeon Pea	Chick Pea	1/Ground-nut	Potato	Sorghum	Tropical2/ Pastures	Maize	Wheat3/	Beans	Cassava
St. Helena						●						
St. Vincent						●						
Trinidad and Tobago									●			●
SOUTH AMERICA												
Argentina	●			●	●	●	●	●	●	●	●	●
Bolivia	●					●		●	●	●	●	●
Brazil	●				●	●	●	●	●	●	●	●
Chile	●			●		●			●	●		
Colombia	●					●	●	●	●	●	●	●
Ecuador	●					●		●	●	●		●
Guyana										●		
Paraguay									●	●		●
Peru	●			●	●	●		●	●	●	●	●
Surinam	●				●		●		●			
Uruguay	●					●	●		●	●		
Venezuela	●					●	●	●	●	●	●	
INDUSTRIAL COUNTRIES												
Albania						●				●		
Australia	●					●				●		
Austria										●		
Belgium	●									●		
Bulgaria	●			●	●					●		
Canada	●			●						●	●	
Czechoslovakia										●		
Denmark						●						
Finland										●		
France	●				●	●			●	●		●
Germany(East)										●		
Germany(West)	●					●			●	●		
Greece									●	●		
Hungary	●									●		
Ireland										●		
Italy	●					●	●			●	●	
Japan	●					●				●	●	
Netherlands	●					●				●	●	
New Zealand	●					●				●		
Norway										●		
Poland						●				●		
Portugal						●				●		
Spain	●			●			●		●	●		
Sweden	●									●		
Switzerland										●		
UK	●				●	●				●		
USSR	●					●				●		
United States	●		●	●		●	●	●	●	●	●	●
Yugoslavia										●		

1/ ICRISAT only 2/ ILCA, AND CIAT (pastures) 3/ includes bread wheat, durum, triticale, and ba distributed by both CIMMYT and ICARDA.

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Appendix Table 2.2: CGIAR Contributions to centers' core programs[a]
($ millions)

	Actual												Est[2]/
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983[1]/	1984
African Dev.Bank							0.025	0.030	0.040	0.045	0.046		
Arab Fund						0.310	0.310		0.255	0.239	0.239	0.230	0.230
Asian Dev. Bank				0.300		0.500		0.700					
Australia		0.005	1.015	1.215	1.745	1.790	2.580	2.650	2.955	3.298	3.773	4.060	4.000
Belgium	0.140	0.600	0.380	0.620	1.740	2.250	2.720	3.085	3.265	2.373	1.823	1.875	1.930
Brazil													1.000
Canada	1.160	1.780	4.675	4.340	5.390	6.800	7.370	7.544	6.875	7.550	8.287	9.949	10.330
China													0.500
Denmark	0.250	0.225	0.370	0.400	0.455	0.615	0.760	1.045	1.210	1.051	0.945	0.940	1.100
EEC						2.500	2.240	3.790	4.545	4.296	4.721	5.155	4.720
Finland													0.500
Ford Fndn.	5.315	3.675	3.000	2.800	2.000	1.590	1.000	1.000	1.300	1.300	1.000	1.294	1.060
France			0.130	0.410	0.510	0.415	0.340	0.675	0.855	0.844	0.891	1.003	1.090
Germany		1.805	3.040	3.935	4.475	5.350	6.760	8.475	10.100	8.368	7.919	7.886	7.550
IDB			2.030	4.120	5.000	5.700	6.185	6.200	6.700	7.400	8.100	8.162	9.100
IDRC	0.175	0.345	0.645	0.990	1.780	1.305	1.045	0.818	1.530	0.961	1.059	1.963	1.810
IFAD								1.550	3.570	5.927	5.937	8.365	7.250
India										0.500	0.488	0.506	0.500
Iran					1.975	2.000	1.000						
Ireland									0.200	0.180	0.212	0.322	0.400
Italy					0.100	0.030	0.100	0.100	0.700	0.965	1.577	6.101	6.790
Japan	0.105	0.230	0.265	0.675	1.200	2.500	3.500	4.845	7.000	8.400	8.850	9.077	9.930
Kellogg Fndn.	0.155	0.290	0.280	0.290	0.300	0.310	0.320					0.635	.340
Leverhulme									0.490	0.585	0.654	0.752	0.810
Mexico									0.495	0.948		0.150	
Netherlands	0.375	0.430	0.555	1.235	1.500	1.720	1.785	2.430	2.600	2.997	3.212	3.528	3.550
New Zealand					0.105	0.025	0.025	0.025	0.025	0.021	0.018	0.016	
Nigeria				0.645	0.645	0.620	0.790	0.825	1.976	1.142	1.205	1.004	0.990
Norway	0.075	0.185	0.445	0.810	1.120	1.510	1.880	1.975	1.995	1.902	1.874	2.176	1.940
OPEC Fund									0.900	1.000	3.548	2.227	2.200
Philippines									0.150	0.500	0.500	0.355	0.500
Rockefeller Fndn.	3.990	4.545	3.500	2.885	2.165	1.595	1.250	1.220	1.600	1.000	0.800	0.522	0.630
Saudi Arabia					1.000	1.000						1.500	1.500
Spain										0.500	0.500	0.498	0.500
Sweden	1.000	0.150	1.490	2.290	2.255	2.240	2.725	2.115	3.390	3.315	2.173	3.051	2.110
Switzerland		0.410	0.140	0.460	0.855	1.205	1.350	1.850	2.450	2.605	2.752	4.894	5.610
U.K.	0.690	1.110	1.920	2.410	2.890	3.515	4.765	6.395	6.790	6.031	6.342	5.909	5.690
UNDP	0.850	1.000	1.465	2.165	1.930	3.500	4.400	3.995	4.615	5.065	6.088	6.849	8.240
UNEP				0.600	0.340	0.340		0.150			0.183	0.129	0.100
U.S.	3.770	5.390	6.805	10.755	14.870	18.140	21.145	24.800	29.000	35.000	40.785	44.550	45.250
World Bank	1.260	2.780	2.375	2.195	6.525	7.850	8.675	10.200	12.000	14.600	16.300	19.000	24.300
Others													
Kreage	0.750												
TOTAL	20.060	24.955	34.525	47.545	62.870	77.225	85.045	99.487	119.576	130.904	143.800	164.633	175.100

[a] Inclusive of transferred special projects.
As of September 1984.

Source: Centers' Program and Budget Papers and accounts, 1974-1984.

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Part II PARTNERS IN COLLABORATION: NATIONAL RESEARCH SYSTEMS AND THEIR VIEWS ON THE CENTERS

Overview

Great importance was attached in this study to the views held by concerned individuals in the national organizations with which the centers have collaborated, should collaborate and doubtless will collaborate in the future. The sheer numbers of such individuals necessitated a case study approach in terms of the countries selected for study and, within these, in terms of the limited cross-section of individuals with whom contact could be made.

The 28 countries selected for case study were intended to constitute a set that was as representative as was possible with this small number. There were several aspects of representativeness; size, importance of agriculture within each economy, stage of economic development (e.g., indicated by average income level), as well as the state of development of national institutions, especially the research service, and last but not least, the intensity of collaboration with the CGIAR system (Table II.1). These several criteria meant that it was not possible, to seek representation across all combinations of all major categories of all characteristics. To this extent, the selection was necessarily arbitrary but it is believed that the panel of countries is indeed broadly representative of the centers' key partner countries in the developing world.

For each country, the person charged with recording national perceptions (usually a national citizen) was advised as to the approximate number and type of people with whom to document perceptions of the nature of the contact with

Table II.1 Characteristics of case study countries, 1980.

Country	Population (mil)	GNP/capita (1982 US$)	Arable land 1982 (mil ha)	Number of agricultural researchers	% of labor force in agriculture 1983
Africa					
Burkina Faso	6.5	210	2.6		79.4
Cameroon	9.3	890	5.9	176	79.4
Ethiopia	32.9	140	13.3	123	77.9
Kenya	18.1	390	1.9	638	76.0
Malawi	6.5	210	2.3	76	81.7
Nigeria	90.6	860	27.9	491	50.5
Senegal	6.0	490	5.2		72.6
Tanzania	19.8	280	4.1	236	79.3
Zimbabwe	7.5	850	2.7	214	57.0
Asia					
Bangladesh	92.9	140	8.9	1514	82.8
Burma	34.9	190	9.6	266	49.7
India	717.0	260	169.5	5947	60.9
Indonesia	152.6	580	14.3	1360	56.5
Nepal	15.4	170	2.3	388	92.1
Philippines	50.7	820	7.8	1330	43.9
Thailand	48.5	514	17.1	8356	73.9
Latin America					
Brazil	126.8	2240	63.0	1613	35.8
Chile	11.5	2210	5.3	171	17.0
Colombia	27.0	1139	4.1	405	24.8
Costa Rica	2.3	1430	0.3	69	33.0
Cuba	9.8	n.a.	2.5		21.0
Ecuador	8.0	1350	1.8	337	42.5
Guatemala	7.7	1130	1.3	908	53.0
Mexico	73.1	2270	21.9	1242	33.5
Peru	17.4	1310	3.2	250	35.2
Middle East/North Africa					
Egypt	44.3	690	2.3	4200	49.2
Syria	9.5	1680	5.2	500	46.4
Tunisia	6.7	1390	3.5		37.9

Source: Population and GNP/capita from World Development Report, 1984 (The World Bank); Arable land and % of labor force in agriculture from FAO Production Yearbook 1983. Numbers of agricultural research scientists derived from information obtained in the impact study case studies and includes the total number of those identified as primarily researchers, excluding, in most cases, university staff.

the centers. The number suggested was related to the size of the country and of its research and related professional services. Particular attention was directed to those parts of the national system that would be expected to have significant dealings with the centers. The guidance offered included suggestions to include a range of professional research disciplines, as well as individuals concerned with the wider implementation of the research findings in commodities or activities of relevance to the centers. Depending on the center and commodity or research program, this implied individuals ranging from specific commodity agronomists and breeders, through to policy makers in and out of national governments. The case study author in each country has prepared a technical paper summarizing the results of each investigation (see Preface). These are intended for publication as CGIAR Study Papers.

With typically 40 to 50 people contacted per country, there was naturally scope for bias in the choice and from the availability of interviewees. These potential biases were brought to the attention of the authors and their assistants and, in documenting the broad summary of such perceptions, the synthesizing authors of this Part have endeavored to correct for any such bias when it was apparent.

The country case study authors used their best judgment as to which individuals to interview. This was done with the aid of a structured check list covering the desired dimensions of the perceptions of collaboration. In some cases, suggestions from the centers about key people to contact were provided to the collaborators. In other cases, individuals were contacted who were judged by the centers to be less than appropriate. Some of these individuals had particular "axes to grind", usually through some less than

happy experience in their association with a center. The authors and synthesizers have endeavored to treat all the opinions collected in a sympathetic and objective manner.

Of course, the centers may well have different perceptions of their relations with and contributions to national programs than do individuals in the national programs. Centers' views are extensively reported in the centers' own publications and hence are in no danger of being forgotten. If divergence between nationals and centers was large and persistent there would be cause for concern about the communications of needs from countries to centers and the centers' responses. By and large, however, the divergence was minor. The views of researchers in partner countries are still reported even where actions have now been taken by centers to improve cooperation.

To summarize, the approach taken, represented a significant part of the effort but is subject to inherent limitations of the subjectivity of all the individuals involved, both those expressing their opinions and those collecting such data, and the partiality in terms of incomplete coverage, both between and within countries. In spite of these limitations, it is believed that the data are unique and valuable in making an independent assessment of the success or otherwise of past collaboration with the centers.

The main reason for committing so much of the resources for this aspect of the work was that, while of incontrovertible importance, it had seemingly never been done before. There is a suspicion in the minds of some that, given the dominance of the centers in supplying information on their activities, the opinions of the partners are too often relegated to a minor place. The present endeavor is an attempt to correct any such imbalance.

As a prelude to reporting the primarily perceptual material of chapters 4 and 5, this Part opens with a brief description of recent trends in national agricultural research systems. This review of national research developments in chapter 3 is intended to be objective in character and partial in scope. In particular, it describes recent changes in the macro research infrastructure itself without confronting other related macro issues. The returns from agricultural research are heavily constrained by prior public investments to provide grassroots rural credit, networks of rural feeder roads, storage and processing facilities, rural electricity, irrigation water, and other rural infrastructures, and revitalized, revamped and reorganized extension system which ensures unambiguous two-way communication links between farmers and researchers, to mention a few. Good decisions concerning these several important and interrelated matters depend on precious information which must be the product of further, hopefully early, insightful research that was beyond the scope of the present study.

The perceptions gathered are reported in detail in the separately published reports of the country case studies. In chapters 4 and 5 they are presented in a structured summary form. The primary partition is into those on relations with the centers, in chapter 4, and those on the contributions of the centers, in chapter 5.

Notwithstanding the several attempts to guard against bias, in the process of assembling this report it became progressively apparent that a subtle, human influence was at work in moderating some of the reporting of perceptions. Few cases of serious conflict between center staff and national collaborators are recorded in the following, yet gossip has it that there have been many. It can only be concluded, with the greatest respect, that some of

those interviewed have exercised considerable restraint in putting their personal misgivings asunder from the positive and constructive attitudes expressed.

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3 NATIONAL AGRICULTURAL RESEARCH

3.1 Introduction

National agricultural research systems in the developing countries have grown rapidly in the past quarter century. The capacity of the national systems, and the growth of expenditure and manpower in these systems, along with other important characteristics are described in this chapter as a backdrop to the environment in which the CGIAR centers operate. Finally, some of the factors associated with growth of the national systems are examined.

3.2 Agricultural Research Capacity

3.2.1 Research capacity in the 1950s

There are few data available on national research systems of developing countries during the 1950s, although it seems to have been a period of slow growth for most. At the beginning of the decade, Latin American countries were investing little in agricultural research. By its end, however, Argentina, Ecuador, Venezuela and Mexico had created "decentralized, autonomous institutes generally organized on the basis of the experience derived from the experimental station system of the U.S.A." (Trigo, Pineiro, and Sabato 1983, p. 126). Much of Africa was still under colonial rule. There were some strong research programs for the export crops, and programs for food crops in some countries. However, little research was done on crops grown only in small-scale farming or on subsistence mixed-cropping systems. In part this arose from the general observation that most subsistence farm households in most places could indeed supply their own food needs most of the time.

Asian countries were in a period of rebuilding following independence. Several - notably India, Sri Lanka, Pakistan and the Philippines - had inherited research systems from a colonial era with a number of well-trained local agricultural scientists. Experiment stations were in place along with an intact institutional research structure. Other countries were less fortunate. Indonesia had very few agricultural scientists, and virtually none with advanced degrees. Thailand had a few more but not many. The decade of the 1950s was a period of slow growth in most Asian research systems. They were not very productive during the decade because of the adjustments caused by independence and the loss of both national and expatriate scientists. Research on export crops continued to have high priority.

3.2.2 Growth in research capacity in the 1960s and 1970s

The 1960s and 1970s were decades of rapid growth of agricultural research systems throughout the world. In Asia, the increases in expenditure and personnel were accompanied by changes in institutional structure and research priorities. National research systems in the 1960s concentrated on adapting modern varieties of wheat and rice, building local staff numbers and centralizing fragmented institutions. The agricultural research council was widely used as a means of centralizing research decisions. The model of the Imperial (later Indian) Council of Agricultural Research, started in colonial India, was adopted in Pakistan, the Philippines, Bangladesh, Malaysia and Indonesia, for example, during the 1970s. There was a shift of research priorities from export and cash crops to the major food grains. Agricultural universities in India and the Philippines became integral and productive parts of the research systems, broadly conceived. The 1970s witnessed a continuation of these trends. There was rapid growth in some of the research systems that had lagged in the 1960s, particularly in Indonesia, Bangladesh

and Pakistan. Most of the new research resources were invested in programs dealing with the major foodgrains.

Peru, Colombia, and Chile during the 1960s followed the example of Argentina by establishing decentralized national research programs. Uruguay did not start a new program but substantially reorganized its previous system, and Brazil made some changes within the traditional structure. In 1973, Brazil created a completely new institution, EMBRAPA, quite different from its institutes of the 1960s. These changes along with the greatly enlarged investment increased the output of the research systems. Semi-dwarf wheat and rice varieties were widely adopted in several countries and maize and soybean output increased in others. Some critics of agricultural research, however, argued that these technologies were not reaching the poor. Several institutional changes were implemented in order to shift the focus of research institutions to the problems of the poor, and to orient many national agricultural professional workers more into direct extension and development activities. At about the same time, support for some of these systems started to decline and several, such as the Peruvian, were almost completely destroyed.

These two decades were periods of rapid transition for many African countries, analogous to the 1950s in Asia. Many countries gained independence and in some cases this was followed by periods of political instability. National research was disrupted by the breakup of regional research institutions, the departure of colonial research workers from many countries, and shortages of local research talent. Only three African agricultural scientists were working in all the experiment stations in Kenya, Uganda and Tanzania in 1964. There have been some dramatic improvements since

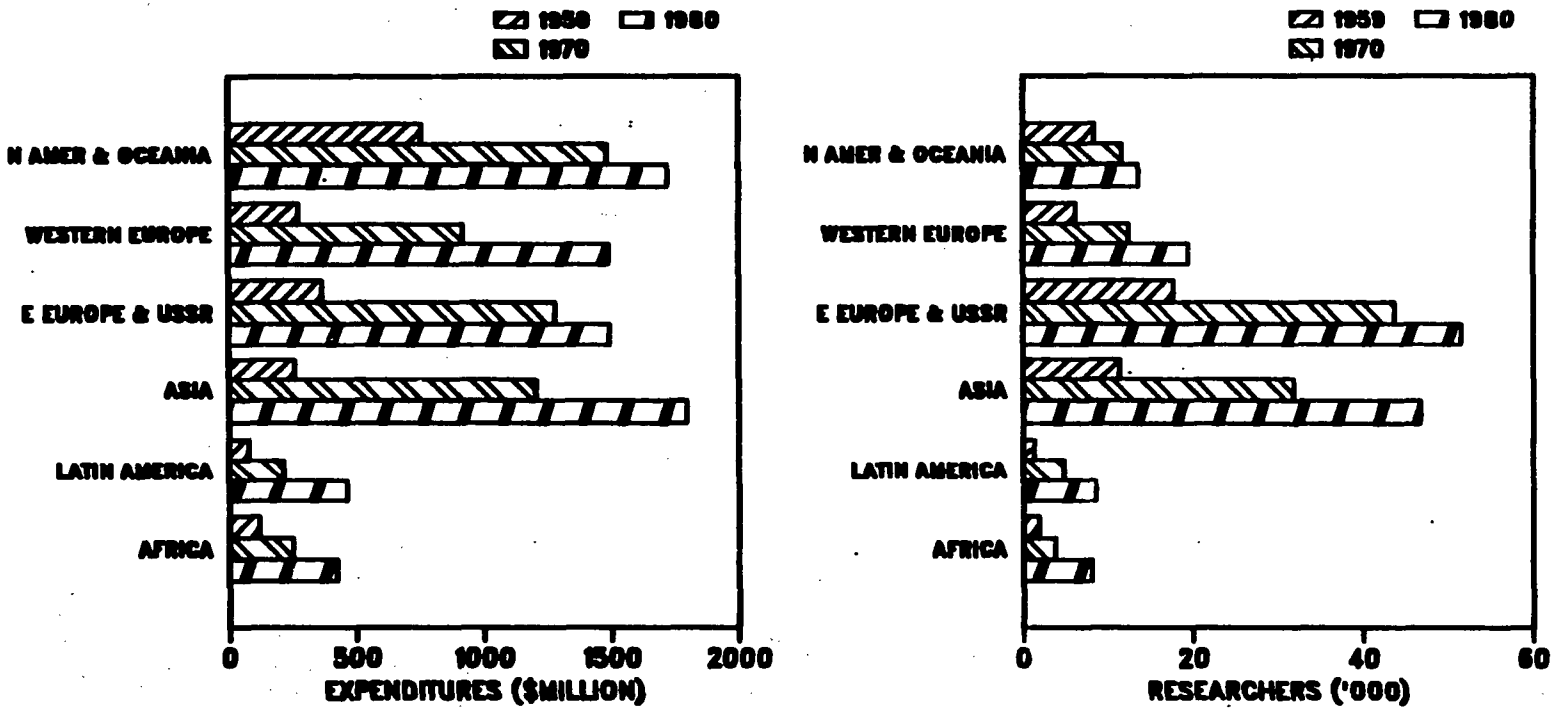
independence, more resources are now invested in research on major food crops, and many African agricultural scientists are being trained - but some problems persist.

For the period after 1959, data are somewhat more systematically available than for previous periods. They have been assembled by Evenson and his colleagues covering both industrial and developing countries (Boyce and Evenson 1975 and Judd, Evenson and Boyce 1983) and by Oram and Bindlish (1981) covering developing countries for the period 1970 to 1980. In addition, there are studies covering specific regions, e.g., Trigo, Piniero and Sabato (1983) for Latin America. The difficulties in collecting such data and in making them comparable, especially making adjustments for inflation and exchange rate movements, has led to some inconsistencies. Fortunately, such inconsistent estimates of expenditure for individual countries are the exception, and the more recent data and the changes over time in the regional aggregates are probably fairly accurate, at least in indicating trends. The trends in expenditure are fairly consistent with trends in the numbers of scientists, both of which are useful for indicating aspects of the development of the systems.

During the period from 1959 to 1980, expenditures on government research increased by a multiple of six in Asia and Latin America and by over four in Africa (Figure 3.1). The regional growth rates were about the same in both the 1960s and 1970s. Asian research expenditures increased in all countries except Sri Lanka, while in Latin America and Africa there was much more variability among countries. Five Latin American countries had a fall in real research expenditures during the 1970s but regional growth was rapid because several large systems, notably those of Brazil and Mexico, grew very rapidly.

Figure 3.1

PUBLIC SECTOR AGRICULTURAL RESEARCH EXPENDITURES AND STAFFING BY REGION, 1959, 1970, AND 1980.



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In Africa, the growth in Nigeria dominated the regional picture but expenditures in South Africa, Kenya and Zimbabwe also grew significantly. These countries accounted for most of the aggregate growth and offset the declines in a number of others.

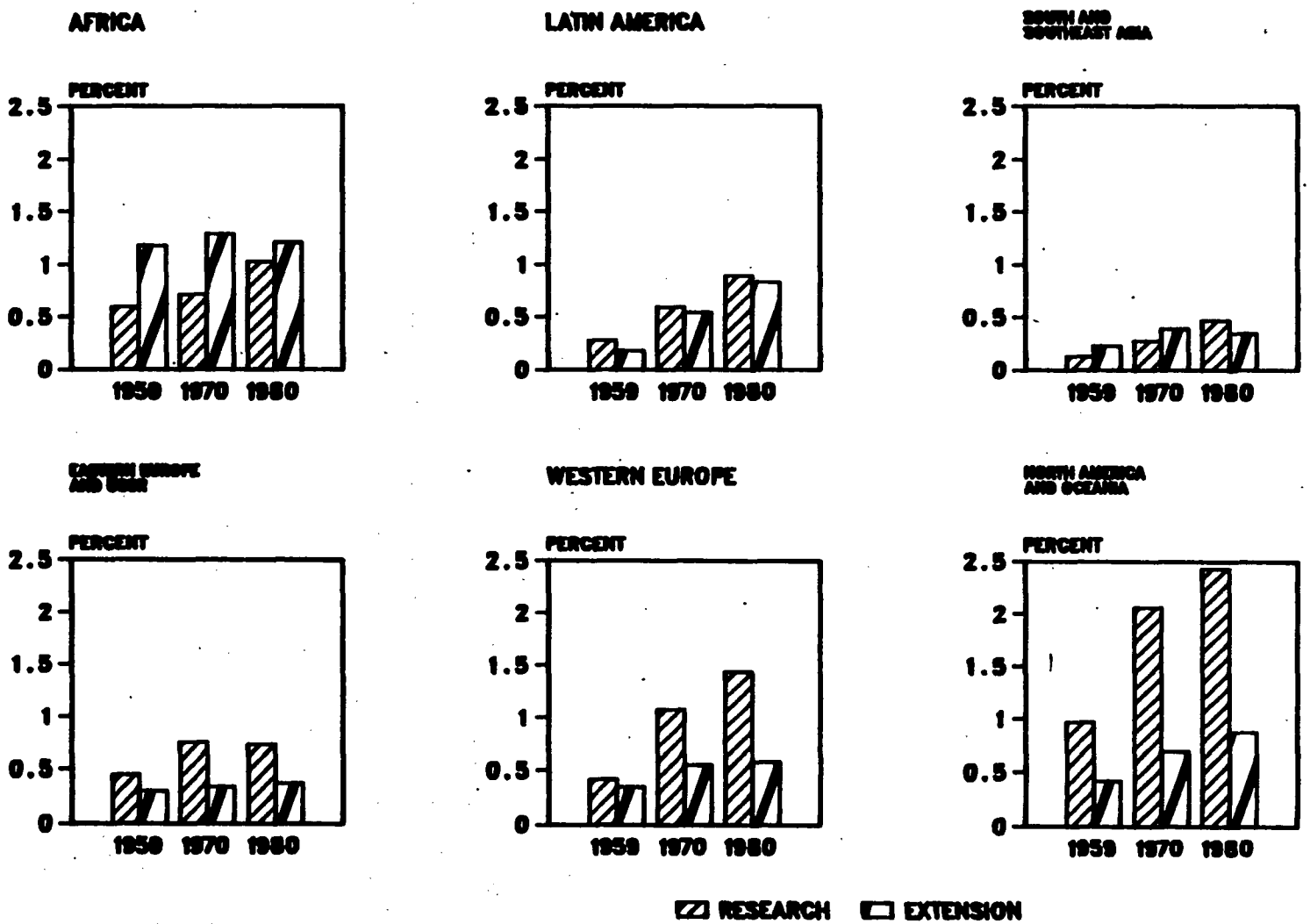
Government research expenditure increased substantially not only in absolute terms but also relative to the size of the agricultural sector (Figure 3.2). In the low-income countries, 0.15 percent of agricultural GDP was spent on research in 1959. This increased to 0.5 percent by 1980. Asia invested a smaller proportion of its agricultural GDP in research than the other regions. In contrast, W. Africa and S. Africa approach the level of the industrial countries, which spent about 1.5 percent of agricultural GDP on research in 1980. Foreshadowing later discussion, and recalling the productivity overview of chapter 1, there is a paradox in relating high investment levels and general slow rates of technological progress in much of Sub-Saharan agriculture — a paradox surely worthy of urgent investigation in further research.

Research expenditure also increased relative to extension expenditures. The low-income countries were spending the equivalent of 0.3 percent of agricultural GDP on extension in 1959 and 0.44 percent in 1980. The industrial countries spent far more on research than on extension, whereas the developing countries spent about the same amount on research as on extension.

The number of agricultural scientists reportedly grew at roughly the same rate as expenditure in Asia and Latin America. Research staff in Africa, however, increased by a factor of almost seven while expenditure increased only four times. This may reflect, in part, a problem endemic to many

Figure 3.2

PUBLIC SECTOR AGRICULTURAL RESEARCH AND EXTENSION AS A PERCENT OF THE VALUE OF AGRICULTURAL PRODUCTION



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national research systems, namely high turnover rates of research staff. The instability thus occasioned by internal migration from the research system to other sectors of the economy (including universities, the private sector and other areas of the public sector) may be economizing of research budgets but it is devastating to research productivity, especially in fields such as plant breeding where gestation periods tend to be long.

In 1980, about 148,000 scientists were claimed to be conducting agricultural research worldwide, 43 percent of them in the developing regions of Asia, Africa and Latin America. The world was investing $7.4 billion annually in agricultural research, 38 percent of it in the developing countries.

3.2.3 Status of national systems in case study countries

The case study countries reflect a wide range of growth in capacity (Table 3.1). In a few, such as Indonesia and Tanzania, agricultural research grew at nearly 20 percent per year. In a second set, including Ethiopia, Kenya, Nepal, Mexico and Egypt, it grew around ten percent annually. In a few, including Zimbabwe, Chile and Peru it grew little or not at all.

There is wide variation in the numbers of researchers across countries, ranging from 70 in Costa Rica to nearly 6000 in India. Likewise, the numbers with master's and PhD degrees ranged widely. Of course, some countries are much larger than others. Computing the number of researchers per million hectares of crop land gives some idea of the range in research capacity across countries. However, the deflator is not satisfactory because a large country with reasonably uniform agricultural resources not require the same degree of research intensity as a highly diverse small country.

Table 3.1 Status and growth of the national agricultural research systems in some of the case study countries

Region and country	Number of agricultural researchers in 1982 excluding university staff: With higher degrees[a]	Total number[b]	Researchers per million ha	Growth rate of no. of researchers: percent	years covered	Source
Africa						
Burkina Faso						
Cameroon		176	-	5	1965-84	CC
Ethiopia	50	123	9	9	1972-82	CC
Kenya	315	638	335	8	1970-82	CC
Malawi	21	76	33	6	1964-83	CC
Nigeria	276	491	18	17	1970-80	OB
Senegal	n/a	196	39	9	1975-84	CC
Tanzania	n/a	236	58	18	1970-82	CC
Zimbabwe	n/a	214	79	1	1970-84	CC
Asia						
Bangladesh	1262	1514	170			OB
Burma	30	266	27			CC
India	547	5977	35			CC
Indonesia	400	1360	95	24	1975-84	CC
Nepal	170	388	169	11	1971-80	CC
Philippines	105	1330	171			CC
Thailand	n/a	8356	489	6	1975-82	CC
Latin America						
Brazil	1275	1613	25			CC
Chile	62	171	32	1	1970-82	CC
Colombia	228	426[c]	104			CC
Costa Rica	7	70	233			CC
Cuba						
Ecuador	75	337	187			CC
Guatemala	30	210	161			CC
Mexico	360	1240	56	11	1970-82	CC
Peru	32	250	78	3	1970-83	CC
Middle East/North Africa						
Egypt	1427	3556	1459	10	1979-81	CC
Syria	55	500	95			CC

a/ Master's and doctoral level degrees
b/ Degree holders and above.
c/ Research workers of ICA.

Source: Country Case Studies (CC) or Oram and Bindlish (OB) and FAO (1984).

3.2.4 Private sector research and development

There are few data on private sector research expenditure in developing countries. Surveys in India and the Philippines (Government of India 1980, NARSS 1971) show private expenditures to be less than 10 percent of government research. Chile has a long history of private sector agricultural research, but it is small relative to the public sector. Zimbabwe has a private agricultural research unit of longstanding. In these and a few other countries like Argentina where there are very active private sectors, the proportion spent by the private sector may be more but, in most developing countries, the private sector probably spends less than 10 percent of what is invested by government research.

Two main types of private institutions conduct agricultural research: private firms such as input supply companies or the processors of agricultural commodities, and groups of farmers or plantation owners who finance and conduct research.

There are several clear trends in private research in developing countries. In Asia, private research during the colonial period was primarily by organizations of producers of export crops. After independence, many of these organizations were taken over by governments or simply allowed to wither away. Processors such as sugar mills, tobacco and rubber companies that conducted research were nationalized in some countries but in others were allowed to operate privately. There probably was a decline in research expenditure by processors. In the late 1960s and 1970s, there was rapid growth in applied research and development work by private chemical and seed companies in S.E. Asia and S. Asia, many of which were local affiliates of

multinationals. These efforts are highly applied and concentrate on technologies that can be embodied in an input that farmers can purchase such as hybrid seed and chemicals. It is not clear whether there has been an increase or decline in private research, but there has been a clear shift from research by private commodity organizations and processors of export crops to research by companies supplying inputs to both foodgrain and export crops. Apart from such overtly commercial activities, the work of non-governmental development organizations and missionaries continues to be most important, albeit often neglected by observers and accountants of research.

There seems to have been the same decline in Africa as in Asia of research by commodity organizations, but the tendency varies considerably among countries. Many of these organizations were quasi-governmental during the colonial period, being then financed out of general government revenues. Others, however, had considerable autonomy from the government. In Kenya and Malawi, private research by farmer organizations remains strong and in Zimbabwe it is increasing in strength. In contrast, the commodity organizations of Tanzania lost much of their strength, and their contribution to research has declined. Private input supply firms have strong research programs in a few countries such as Zimbabwe but, in most of Sub-Saharan Africa, they still have small research programs if any.

Private research in Latin America was conducted in the 1950s primarily by processing and trading firms such as the banana companies, and by such commodity organizations as the coffee growers of Brazil and Colombia. Such research programs, including those of processing and trading firms such as United Fruit, have declined in recent years. Research by input supply firms has grown rapidly in Argentina, Brazil and Mexico. Input supply firms have

been attracted to these markets by their similarity to U.S. agriculture and the size of the markets, which grew in the 1960s and 1970s. Private commodity groups such as the Brazilian and Colombian coffee growers have continued to do research, and several new groups such as the sugar producers of Colombia have built strong research programs. Regional producer groups have started to invest in applied research and extension in Argentina and S. Brazil.

Farmers as individuals are also important contributors to "research" within the private sector but, data collection on such informal on-farm activities being what it is, there is virtually no documentation of this surely important dimension of applied agricultural research.

3.3 Causes of Growth in National Research Investment

3.3.1 Demand for research

Food crises, leading to political pressure by consumers for reliable food supplies, were particularly important stimuli to national research investment in Asia in the 1960s and in Africa in the late 1970s and 1980s. There was an increasing demand in the urban sector for foreign exchange to purchase industrial inputs and so forces developed in this sector for reduction in food imports and expansion of export of rural commodities. Urban groups induced governments to invest in agriculture in order to provide adequate food and maintain economic and social stability. The food crises also induced donors to invest in food production in developing countries.

The dramatic performance of the fertilizer-responsive rice and wheat varieties - a development in which the international agricultural research centers played an important part - was another major factor leading to

increased research. The global publicity surrounding the green revolution changed the perceptions of the planners in developing countries and of donors in industrial countries about what research could do. The alternatives to research were gradually perceived to be less attractive. The failure of major investments in extension to achieve rapid growth led to much disillusionment with extension by some agencies. In a number of countries - especially in Asia but also in parts of Latin America - land was no longer so cheaply available for increasing production. Increasing investment in research was seen as one answer to the demands for more agricultural production.

The demand for food, and for export crops in Africa, was rapidly increasing during the 1960s and 1970s. The groups that would benefit from research were similar to those who benefited in Asia and Latin America - urban consumers, governments which collected taxes on exports and industrialists who wanted cheap labor and foreign exchange. However, two factors differentiated Africa from Asia and Latin America and made it unclear whether there was increased domestic demand for research or not. First, the research systems were undergoing reorganization and land was still generally available for extensive expansion. Even now there have been no major success stories in Africa comparable to the green revolution in Asia. Second, as Lipton (1984) points out, during the 1970s foreign aid donors financed a much larger portion of the growth of African agricultural research with more external influence than in the other regions: "so-called 'national African agricultural research' in much of Sub-Saharan Africa - though there are important exceptions, such as Kenya - reflects foreign money, personnel, and intellectual commitment overridingly,... to a much greater extent than in other developing regions."

3.3.2 Public, private and international interactions

Over the 1960 to 1985 period the growth of publicly financed national research, private research and international research was mutually reinforcing. The international centers built on the knowledge base of national systems in the industrial and developing countries. They assembled germplasm from existing collections of national programs and added large amounts through collecting expeditions mounted cooperatively with national programs. They hired research workers from strong national programs such as India's, and brought expatriate researchers from industrial countries. Mexico's national program on wheat and maize, which had been greatly strengthened with Rockefeller Foundation assistance, was the basis of CIMMYT. IRRI was able to draw on germplasm collections from national programs in Asia, and crossed Taiwanese and Indonesian varieties to develop IR8. The Indian research system's coordinated sorghum and millet improvement programs, which had been organized with the assistance of the Rockefeller Foundation, provided the bulk of ICRISAT's initial germplasm collection and a considerable number of Indian scientists for ICRISAT and other centers.

It is clear that the international centers cannot have much impact on food production unless there are strong national systems with which to work. Except for a few early cases such as Mexipak wheat and IR8 rice, the national systems must custom-fit technology for farmers' conditions, adapting technological components made available through international networks supported by the centers. In many cases the centers' research methods and ideas make it easier for national researchers to test and adapt the centers' technology to local conditions. The centers help to make national research systems more productive by providing germplasm, training, publications, and networks of professional colleagues. They have helped to improve productivity

by providing assistance to improve organizational structures, planning, and management. The publicity surrounding the green revolution helped to make it possible to increase the government budgets for foodgrain research.

The growth of private sector research and development activities has also been reinforced by the development of public sector research activities. The growing use of commercial seed, fertilizer, pesticides, and machinery, based in part on the development of crop varieties that are responsive to these inputs, has provided the basic incentive for research by input supply companies in developing countries. Private companies hire researchers from the government system and from among the pool of researchers who have undergone training at the centers and elsewhere.

3.4 Adequacy of the National Research Systems

3.4.1 Underinvestment in national research

Despite the rapid growth of national research systems over the past quarter century, there are signs that the research systems of many countries are not adequate to meet their needs. There is evidence that insufficient financial resources have been invested in research, the number and quality of scientists is inadequate and that the available resources are not allocated efficiently to meet either the productivity or income distribution goals of the government.

There is no fixed amount of money nor percentage of GDP that is the optimal investment in agricultural research for every country. Several authorities have suggested that two percent of the value of agricultural GDP is an appropriate level to aim for (IBRD 1981). Figure 3.2 shows that in 1980

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only North America and Oceania met this goal and Europe came close. Among developing regions, Africa comes closest with about one percent, then Latin America with just under one percent and Asia which spends about one-half of one percent.

A better measure of the adequacy of research investment is the expected rate of return to investment in research. If this rate is greater at the margin than the returns to alternative projects in which the government or the private sector might invest, more should be invested in research. There is now a considerable body of literature that shows that returns to past investments in research have been much higher than alternative investments. Some of the evidence on the returns to research in some developing countries is summarized in Figure 1.2. Most of the estimates of returns to research have ranged from 30 to 60 percent internal rate of return, with some projects yielding much higher returns.

Where comparisons have been made, there is a tendency for returns to extension to be lower than those to research. In India, rates of return to extension have been found to be some 15 to 30 percent (Evenson and Jha 1973, Mohan and Evenson 1975). Rates of return to education and infrastructure projects have typically been in the 10 to 15 percent range. Surface irrigation projects in India were recently estimated to yield 12 to 14 percent (Abbie et al. 1982).

There has been considerable discussion within national systems and the donor community of the adequacy of links between national research systems, extension systems and farmers. Linkage deficiencies slow the flow of technology to farmers, lead to inappropiate research because researchers are

not conversant with farmers' problems, make it difficult to develop grassroots support for research budgets, and result in returns to research and extension lower than they might be.

Comparisons of rates of return suggest that there has been underinvestment in agricultural research in developing countries - particularly in Asia which has about half the research intensity of other regions. However, the data are silent on Africa, where studies of returns to research have seemingly not been conducted. High returns to research there could be expected if it is effectively organized and conducted. The word "harmonized" has been used to describe this happy, albeit perhaps still hypothetical, state and, as a concept, it can be readily intended to describe also the preconditions for effective collaboration of national programs with the international centers.

3.4.2 Adequacy of human resources for research

It is quite possible for the expenditures of a country or region to appear as possibly adequate using research a intensity measure (Figure 3.2) but, in fact, not to be. In Africa in particular, researchers are expensive and the value of agricultural output of the countries is low, which raises the research intensity measure. It is important, therefore, to look at other measures of adequacy such as the number and quality of research staffs.

Larger countries could be expected to need more researchers, and smaller ones fewer, in order to have the same relative capacity. Very small countries, it has been hypothesized, might need some minimum number in order to achieve a "critical mass". Table 3.2 shows data on agricultural area and number of researchers. Clearly, the industrial countries, especially Europe,

Table 3.2 Number of researchers, agricultural land and indicators of research adequacy, 1980.

	Arable and permanent crop area	Number of agricultural scientists	Scientists per million ha	Research expenditures	Expenditure $ per hectare
	(million ha)	(thousands)		(1980$m)	
India	169	2.3	14	120	0.7
China	100	17.3	173	643	6.4
Other developing Asia	113	9.0	80	224	2.0
Africa	130	5.7	44	363	2.8
Middle East/N. Africa	104	4.7	45	187	1.8
Latin America	171	8.5	50	463	2.7
E. Europe/USSR	278	51.6	186	1,493	5.4
W. Europe	95	19.5	206	1,490	15.7
N. America/Oceania	280	13.6	49	1,722	6.2

Source: Area data from FAO, other data from Judd, Boyce and Evenson (1984)

have high capacity, even judged against land area, but the developing countries have even lower levels than suggested in Figure 3.2. A list of all those with the lowest level of capacity is shown in Table 3.3. Twenty countries have fewer than 50 agricultural researchers in total, including researchers at all levels of training. These 20 countries may be considered, albeit somewhat arbitrarily, as having below the number needed for a "critical mass" for an effective research program. Twelve of the 20 are in Africa and the others are small island countries in the Pacific or Caribbean. In addition to those countries which may lack some such minimal number, several countries have fewer than 25 scientists per million ha of arable land. Using this ratio, 9 countries in Africa fall in this additional category, while all countries in Asia have 40 or more and all countries in Latin America have 30 or more. Thus, Africa contains many countries with possibly inadequate levels of capacity, despite the aggregate data that suggest that expenditures in Africa are high.

3.4.3 Adequacy of allocation of resources

Research resources must be allocated among many different and complex activities. There are few useful measures with which to judge the efficiency of research-resource allocation decisions although many different measures have been used, such as relative shares on import earnings, shares in government revenues from agriculture, etc. One aspect that has received much attention is the allocation between different commodities. Other bases that could be used to allocate resources include different inputs - seeds, soil, fertilizer, irrigation, etc. - or different professional disciplines. Data are reasonably available only on the allocation of research resources by commodity. There are some data on the disciplinary breakdown of a few national research systems.

Table 3.3 Developing countries having fewer than 50 agricultural researchers or fewer than 25 researchers per million hectares of crop land and some additional reference areas, 1980

Country	Arable and permanent crop area (000 ha)	Agricultural researchers Number (1980)	Agricultural researchers per million ha	Research expenditures ($/ha)
	Countries with fewer than 50 researchers			
	(thousands)			($/ha)
Cape Verde	40	6	150	n.a
Tonga	53	8	151	5.4
Solomon Islands	52	8	154	6.4
Mauritania	195	9	46	4.4
Lesotho	292	13	45	1.0
Gambia	270	13	48	0.3
Benin	1795	21	12	1.0
Barbados	33	23	697	15.2
Fiji	236	23	93	6.5
Somalia	1066	28	26	0.5
Burundi	975	28	29	0.7
Guyana	380	35	92	4.2
Haiti	890	37	42	0.3
Chad	3150	40	13	0.3
Malawi	1305	41	31	1.8
Jamaica	265	41	151	1.9
Trinidad & Tobago	158	43	272	2.7
Liberia	371	45	121	1.9
Mali	2050	47	28	1.8
Togo	1420	49	35	0.9
	Countries [a] with fewer than 25 researcher/million ha			
Uganda	5680	58	10	0.9
Ethiopia	13880	145	11	0.2
Zaire	6314	97	15	0.5
Nigeria	30385	491	16	2.6
Niger	3550	59	18	0.4
Zambia	5108	96	19	0.2
Senegal	5225	105	20	1.2
Sudan	12417	272	22	0.8
Cameroon	6930	156	23	0.5
	Some contrasting areas			
India	169130	2345	14	0.7
N. America & Oceania	280446	13607	49	6.2
Brazil	7120	2935	41	2.4
W. Europe	95025	19540	206	15.7
Japan	4881	15671	3211	140.2

[a] In addition to those also having fewer than 50 researchers.
Source: Area data from FAO (1984), other data from Judd, Boyce and Evenson (1984).

A rough rule of thumb for the efficient allocation of resources between commodities, known as the congruence rule, is that the share of research resources allocated to each community be roughly equal to its share of the value of agricultural output. Another way of saying the same thing is that the research intensities (research expenditure divided by value of output of each crop) should be equal. Figure 3.3 shows the research intensity of major commodities across all developing countries. Coconuts, sweet potato and cassava have the lowest intensity — less than one-tenth of one percent of the value of output of each commodity. They are followed by cotton, maize, groundnuts and rice which also have low levels of investment. The commodities with relatively high levels of research investemnt are cocoa, coffee, livestock, and soybeans, each receiving over one percent of the value of output going to research. The CGIAR centers taken as a whole spend a small amount relative to national rsearch investments, are concentrated on many fewer crops than national research, and conduct research exclusively related to food (chapter 2).

Figure 3.4 shows congruence measures on four commodity groups for several developing countries. The line of congruence running diagonally across each diagram defines where the proportion of research investment is identical to the proportion of output value contributed by each commodity group. Points below the line indicate less than proportional investment in research on a commodity while those above it indicate where investment in research on a commodity is more than in proportion to its contribution to output. Such measures are, however, very partial indicators because they take no account of either the different stocks of knowledge concerning different

Figure 3.3

RESEARCH EXPENDITURES AS A PERCENT OF THE VALUE OF COMMODITY PRODUCTION, AVERAGE 1972–79, 26 DEVELOPING COUNTRIES AND THE CGIAR CENTERS

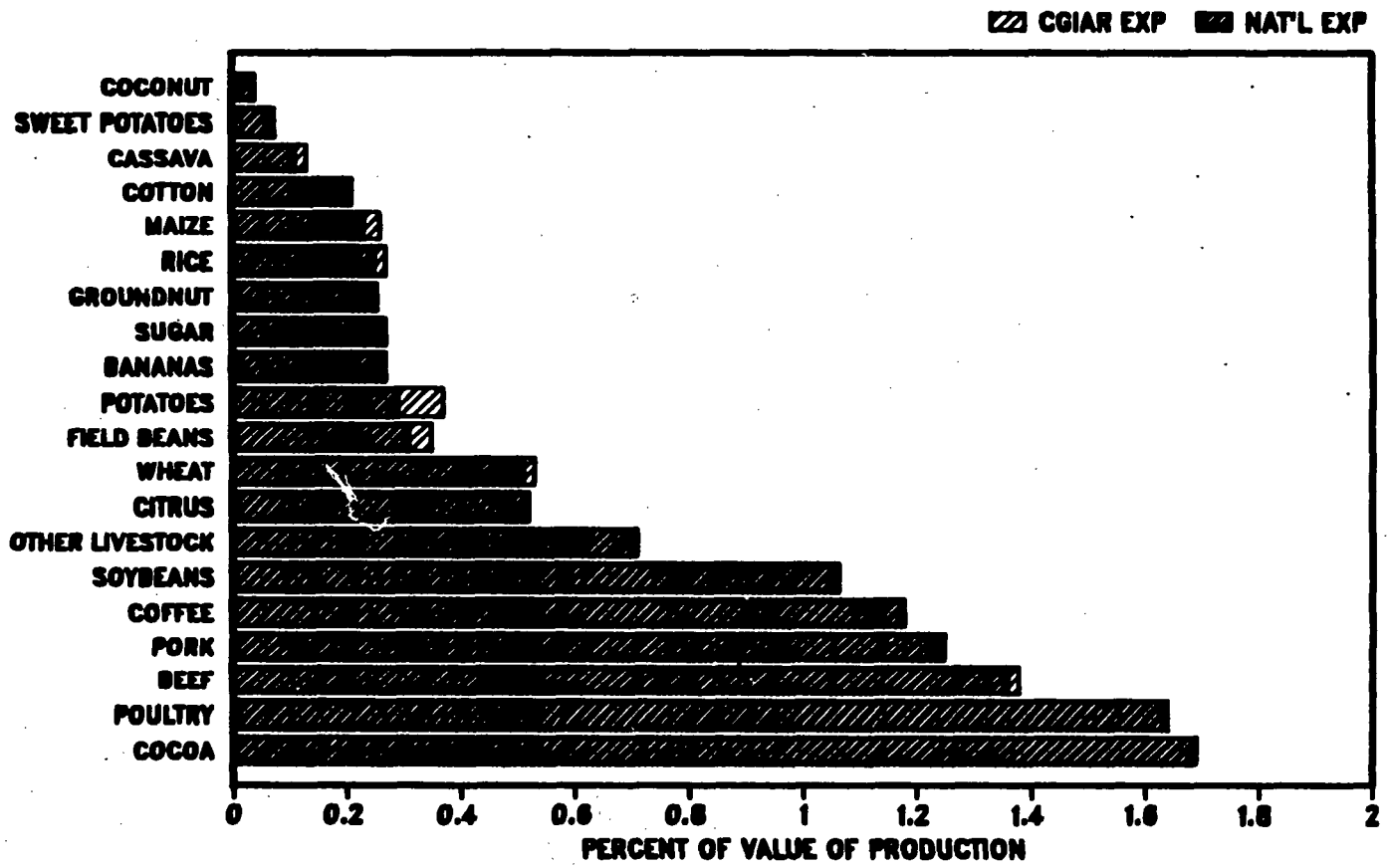

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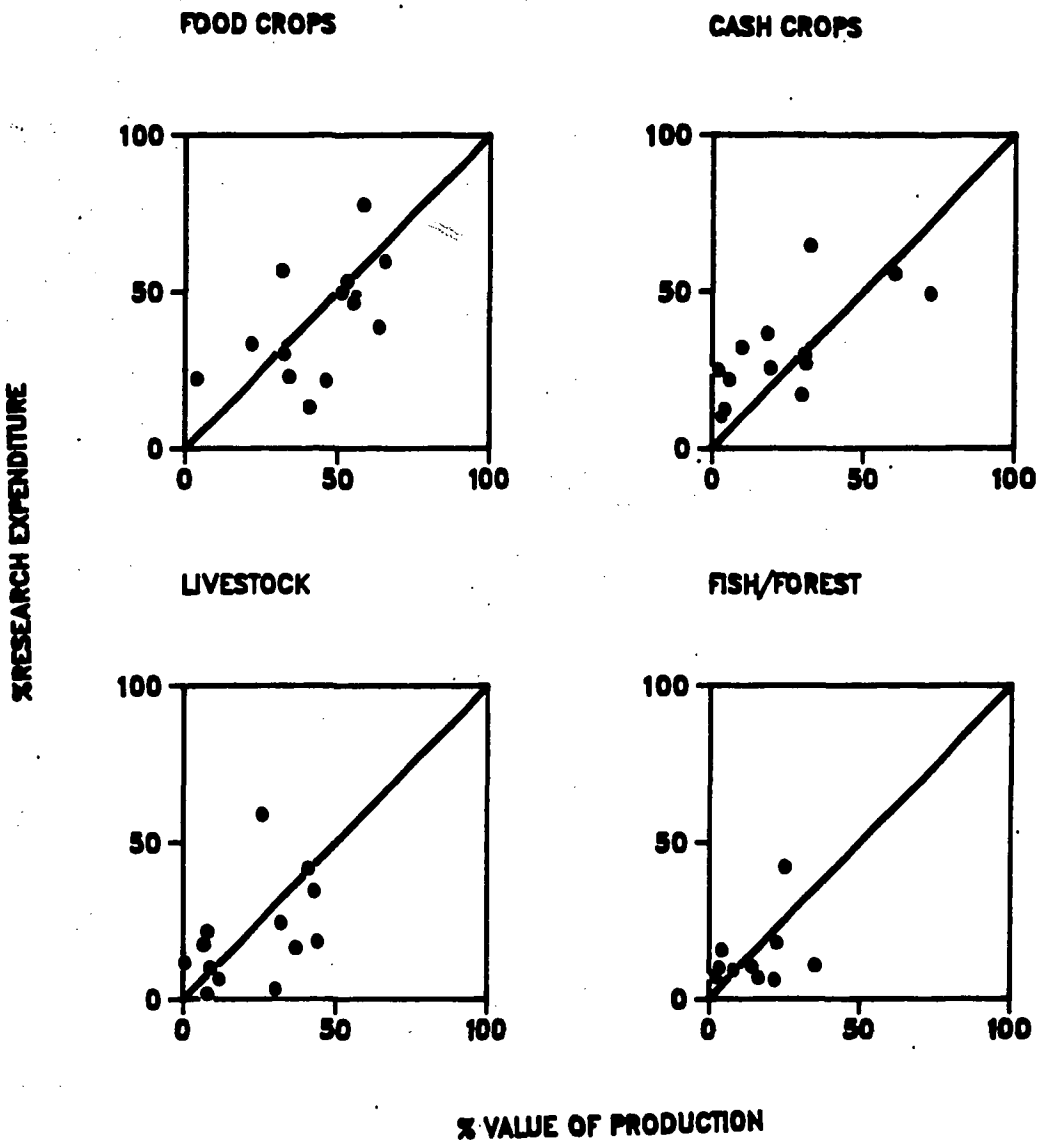
Figure 3.4

CONGRUENCE OF RESEARCH EXPENDITURES AND VALUE OF AGRICULTURAL OUTPUT, 14 DEVELOPING COUNTRIES, 1980 (ORAM AND BINDLISH)



commodities or of the opportunities for technological progress that they present in different ecologies.

Other informational shortcomings curtail progress towards more efficient allocation of research resources. Data on the diversity of the agro-ecological environments in which farming takes place are often fragmentary in both physical and social dimensions. Good decision making about research opportunities depends on good information which is too often sparse. National and international authorities must continue to strive to improve the quality and quantity of data on the environments in which agricultural research is and should be directed.

Other challenges for research planners that have not been addressed here, but which surely must be considered in the context of specific countries and regions, include criteria for allocating institutional responsibility for basic, applied, adaptive, and operational research between different tiers of government (federal, state and local governments) and of allocating institutional responsibility for different categories of research as between national systems and the CGIAR system. Insofar as the CGIAR is concerned, these issues are handled by the Group with advice from its Technical Advisory Committee. Within the centers, ISNAR is charged with assisting national authorities in the challenging work.

3.5 Coda

* There has been rapid growth in the national agricultural research systems in developing countries during the past quarter century. Publicly funded research makes up the major part of agricultural research and has led the

rapid growth in the national systems but, in several countries the private sector also has grown quite rapidly.

* The national systems have progressed most steadily in Asia where growth has occurred in real expenditure in almost all countries. There was an initial period of institutional instability but most countries now seem to be developing effective national systems.

* Latin American research systems in aggregate grew very rapidly but, unlike for those of Asia, the real research expenditures of some countries declined during the 1970s. There was also a period of reorganization in several countries.

* Aggregate growth in African research expenditure was high but, as in Latin America there was considerable diversity across countries. Many African research systems were caught up in the larger national problems of adjustment after independence. Some countries had fairly radical and disruptive changes in their research systems while other systems remained highly dependent on and, in some cases, essentially as parts of, foreign research systems.

* Food crises, leading to political agitation by consumers for reliable food supplies, contributed to the growth of agricultural research expenditure, particularly in Asia in the 1960s and in Africa in the late 1970s and 1980s.

* Agricultural research was increasingly seen in the 1960s as one of the main means for facilitating greater volumes of food production. The rates of return to agricultural research in Asia and Latin America were very high. At least equally important, the publicity surrounding the green revolution changed the perceptions in developing countries and donor communities about what research could do. In a number of countries - especially in Asia but also in Latin America - underdeveloped land was no longer readily available for increasing production. Such countries increased investment in research as one response to the demands for more agricultural production.

* There are still weakness in many national systems. Even in some of the large research systems of the developing countries, there is evidence of underinvestment in research. The smaller developing countries face continuing challenges of educating and retaining sufficient researchers.

* Some commodities have been neglected historically and continue to be neglected today. Many research programs may not be efficiently organized to make the best use of the resources available. Assistance from international agricultural research centers can and does play many important facilitating roles.

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4 NATIONAL VIEWS OF RELATIONS WITH THE CENTERS

4.1 Introduction

There are, of course, many differing views of relations with the centers held among the partners in collaborative endevors. Naturally, these reflect the many differing forms and histories of contacts, not to mention the chemistry of interpersonal relationships. Generalization across such diversity is very difficult and runs a danger that the picture revealed may seem static when, in fact, such relationships and partners' views of them are dynamic and evolving.

4.2 Nature of Contacts

4.2.1 Different countries, commodities and modes of contacts

The history of contacts within a country is closely determined by the establishment of the centers and their development over time. The initial contacts were with the organizations antecedent to the centers, particularly the Rockefeller Foundation programs of technical assistance to selected countries, in Latin America and Asia. With the establishment of IRRI and CIMMYT in the early 1960s, contacts were broadened to a much wider range of countries through Asia and Latin America. Initial contracts in Africa and the Middle East were more sporadic. The early contacts were predominantly with rice, wheat, and maize research personnel, although not all countries at that

stage had active separate research programs on these commodities. However, the centers sought out individuals who were concerned with these crops and developed good working relationships, especially, in the first instance, with plant breeders.

As the centers' operations encompassed other crops and matters through the 1970s, contacts became much wider and, with the passing of time, the geographical scope of contact also increased across all research issues of concern to the centers. Each center, pursuing as it does its set mandate in the best manner that it perceives to be possible (chapter 2), has its own priorities for the ways in which contact can be generated over time. This has necessarily meant that countries that are perceived either as being relatively well able to handle their own research needs or as presently growing very little of a center commodity, are not given close attention while the scarce resources are addressed to those that have greater opportunity for earlier significant impact. Thus, in reflecting on the cross-section of experiences reviewed in this chapter, the reader needs to bear in mind the temporal evolution of the system.

4.2.2 Initiatives for contact and collaboration

Initiation of contacts between INIA in Mexico and the Indian agricultural research system regarding semi-dwarf wheats started before CIMMYT was founded. The Indian wheat scientists were looking for stiff-stemmed fertilizer responsive varieties and rust resistance in the USDA wheat

nurseries. In the early 1960s, some varieties that were developed by the INIA-Rockefeller program looked promising to Indian scientists and they invited Dr. N. Borlaug to visit India. This was the beginning of a long, successful relationship.

The main facilitators of contact during the 1960s between the then existing centers -- CIMMYT, IRRI, CIAT, and IITA -- and the national programs of most countries were the Ford and Rockefeller Foundations. They had already been involved in working to develop national systems in a number of countries, and they helped to found the centers. Indeed, many of their staff members moved from foundation assistance programs to being staff members of the new centers or working directly in national programs. Thus, it was natural for them to play the role of matchmakers. In addition, they had the resources, at least initially, to make sure that the match was beneficial to both parties.

A fundamental principle of any successful cooperative activity is that all parties involved should feel individually advantaged. Positive interactions then reinforce perceptions of individual benefit. Original contact, at least in the early days of the system, usually came from the centers themselves. Considerable resources were devoted to engineering an appropriate array of contacts within target countries. The centers endeavored to seek out individuals seen as being likely to be effective in the centers' terms. Hence there was bias as to personality type and program orientation in order to have the best chances of successful future collaboration.

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Good news travels quickly and, especially after some of the early successes in plant breeding and release of the first modern varieties, many national scientists were eager to strike up closer contact. To the extent that the international centers spanned the range of commodities on which national research centers were actively engaged, this was fairly easy to organize. Willing providers stood ready to assist whoever expressed interest in the national programs. Scientists working on crops not yet covered by the centers had to find other collaborators and sometimes this led them to change to work on crops that were covered. This surely induced some distortions within national research systems as talented national agricultural scientists responded to a variety of informal signals, especially related to financial resources for research on crops of interest, which may be viewed as having either facilitated desirable attention to or distorted needed attention away from different crops.

Now that the major food crops are better served by the present set of international centers, including those centers not within the sponsorship of the CGIAR, the distortions are more between food crops and other crops, especially "export" crops such as beverage crops (e.g., tea, coffee, and cocoa), fiber crops (e.g., cotton, jute) and other tropical tree crops (e.g., coconut, oil palm and rubber). The swing to food crops may have gone too far in some countries, for example in Kenya and Tanzania, the proportions of research funds going to coffee, tea, sisal and pyrethrum are far below their contribution to value of output. However, most countries' export and cash

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crops still receive a higher proportion of the research budget than they proportion of the research budget than they contribute to the value of output. The very existence of the Consultative Group and most of its centers is due to a widely held perception that, hitherto, the biases of agricultural research were towards export crops to the neglect of basic food crops.

In a number of countries, centers have been caught in misunderstandings between different parts of the national systems. This problem was mentioned in the Philippines, India, Nigeria and Thailand, for example. In some systems there are tensions between the research institutions themselves and the Agricultural Research Council or parallel institution that controls the allocation of research resources. The research institutions want to deal with the centers as directly as possible to receive the maximal amount of support, in whatever form, and to pay the lowest cost in terms of "red tape", bureaucratic delays and inter-departmental frictions. The controlling institution wants to ensure that the centers are fitting into national priorities and that it received its perceived rightful share of the services provided.

The centers seem to have done fairly well in not being involved in such misunderstandings. There are exceptions, however. It was reported that CIAT had an abortive beginning of a regional program in the Philippines because it established its S. E. Asian regional cassava center at the South East Asia Regional College of Agriculture (SEARCA) and conducted local trials at Mariana Marcos State University, a provincial institution in an area that grows little

cassava. It did not work closely with PCARRD, the national research coordinating council, or the Bureau of Plant Industry in the Ministry of Agriculture. Large yield advantages from the new technology were reported in the press and these were subsequently some misunderstandings and clarifications about which organizations were doing which activities. CIAT was caught up in the clarification process between different institutions and personalities. The fact that this was the only such example of bureaucratic conflict brought to the notice of the team perhaps indicates something about the restraint and positive attitude of interviewers and the researchers they interviewed.

The judgment of whether a research worker feels individual advantage through the workings of an outside body is a delicate one which broaches issues of autonomy and self-determination in research programming, the role of the individual in creative pursuit of knowledge, and a balancing of the benefits of receipt of needed assistance against objectionable feelings of being patronized that may go with some forms of external assistance. Judging by the generally positive attitudes towards the international centers revealed, it seems that the centers have been fairly successful in drawing this fine line.

Working-level researchers in India made clear their appreciation of specific contributions of the centers such as enhanced germplasm, innovative screening methods, farming system research approaches, economic studies and technical-level training. Those who had participated in center sponsored activities rated them as highly useful. At the same time, among directors of research programs there was a general belief that the centers were doing little that was unique compared with India's own research.

Several research administrators expressed their appreciation for CIP's style of entering a country and working with the local system. CIP's model is to send a team from CIP to work with counterparts from the national research and production system to draw up a plan for potato improvement. Then they determine what role CIP can play - not only in research but also in such areas as clean seed production. Once there is agreement on the respective roles of CIP and the national program, the project starts. This process is perhaps slower to get moving than other ways but it was clear from the reaction of the national systems that they felt that they had greater equality in their collaborative work with CIP than with the other centers.

The perceptions held are not uniformly enthusiastically positive, as is elaborated in chapter 5 in considering particular center "products". This diversity naturally reflects the inevitable results of individual personality traits and limitations inherent in the operation of particular programs in which the centers have been engaged.

4.2.3 Collaboration vs paternalism

Givers of aid are not always known for the benevolence or sensitivity that may or may not characterize their endeavors. Collaboration has always been one of the key elements in the centers' operations. This is achieved by scientist-to-scientist contacts and through participation on centers' boards of trustees of persons serving in their individual capacities. However, administrators in some countries were critical of the functioning and

composition of the boards of the centers, and some in Bangladesh felt it was important to have an official representative on a board who could accurately present the government's priorities.

Since the centers' emphasis on collaboration, it is natural to ask how effectively this works in practice. It is easy to imagine an institution staffed with experienced individuals adopting an attitude in their work of "we know best that this is how you should do it". Such an attitude may be described as paternal, dictorial, arrogant or bullying.

For example, respondents in Brazil, Bangladesh, India, Colombia, the Philippines, Mexico and Nepal mentioned some high-handed attitudes in earlier days of their associations with the centers. It was not possible to track down all the details of such negative feelings but it seems that, to the extent that there were problems, they tended to be isolated and associated with a few strong-minded individuals at centers who played insufficient attention to the niceties of their working relationships with their partners. Doubtless there were also then greater difficulties in finding appropriate partners which may have aggravated these difficulties.

CIAT has influenced bean research in Chila through continuous review and discussion of approaches and methods. It introduced the strategy of broadening the genetic diversity in the Chilean program. However, it was felt that "on occasions CIAT may have been too overbearing in its assistance on research methods". In more recent times, doubtless reflecting a degree of

maturation on both sides of the collaborative arrangements, there have seemingly been much better relationships established.

By and large, respondents were very positive about the quality of their professional association with colleagues in centers.

4.2.4 Nationalism and internationalism in cooperation

Among the personal attributes desirable for effective service in an international agency, such as one of the centers, is a strong sense of internationalism, fired by a conviction that people in many different parts of the world can be assisted through the endeavor. This perspective is not necessarily shared by all collaborators who typically are obliged to take a more parochial attitude to their work. They are usually working for the improvement of particular groups, almost invariably within a particular country.

Comments by respondents in countries typically reflected frustration with the centers' focus on world or regional responsibilities rather than on the range of problems most pressing to the host country. This is surely inevitable given the centers' international responsibility in their narrow mandates and the requirement of the host country national program to cover a broad range of agricultural research issues. Researchers in Mexico and Ecuador, for instance, noted that center scientists during brief visits confined their attention to center-related research, even where that formed only a small fraction of the national scientist's activities.

This tight focus on their specific responsibilities is probably to the credit of the center scientists. However, it may result in missing some opportunities for seeing the more narrow problems in their wider context and hence modifying their objectives and activities. Center staff resident in non-host countries seem to be more successful in taking a broader view of national research issues, as they have both the opportunity and incentive to do so.

4.2.5 Features of successful partnership

Further features of arrangements between partners and centers can be mentioned as forstering a more successful partnership. Some of these features contrast with relationships established with some donor agencies.

Respondents cited continuity of association as being very important in successful collaborative research. Some people contrasted their experience with bilateral donors who typically have projects defined over a fixed, say, three- to five-year term, such that the external resources, including especially any expatriate staff, vanish at the termination of the project. The centers, on the other hand, have developed long-standing associations. Breeders appreciate the regularity with which center staff come in to review jointly the progress of a crop improvement program, for example. There is also a reasonable expectation that assistance will be forthcoming long into the future. This adds a certain calm to the collaborative aspects of the research programs that typically are necessarily long-term.

Consistency is another feature. Providing that a service is basically good, if it can also be consistent, all concerned stand to gain. The fact that so many individuals rated the consistency of center services so highly, speaks well for the centers in that, through effective recruitment policies, they have been able to maintain such consistency over long periods, even with the turnover of staff.

The alternatives for providing genetic resource exchanges of the type offered by the centers are generally not extensive. Indeed, the very existence of the centers in most cases is to fill uniquely a gap that donors and others have detected in institutional arrangements in the world. Not only is there the fact of uniqueness in many centers' operations but there is also the perception among many respondents that indeed this is the situation. If assistance were not forthcoming from a center for supply of germplasm of a particular crop, rightly or wrongly, it was often felt that no effective substitute arrangement would be found. The frequently voiced desire for the CGIAR to work on cash or export crops reflects this (see section 4.3.2).

It is not universally the case, however, that there is no substitute for the centers exists. Other organizations conduct workshops and conferences, provide short-term training opportunities and publish newsletters. A number of researchers in partner countries were asked how important these three categories of services provided by the centers were for their work. Respondents were also asked to rate the importance of the same services as

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provided by other international and bilateral organizations. Workshops and conferences organized by centers were rated higher than those by other institutions in all countries except Mexico. But the difference was minor in Brazil, Ecuador, and Guatemala and Costa Rica. Center training programs were similarly rated higher in all countries except Mexico. Center newsletters and other publications were rated higher in all countries.

4.2.6 Networking approaches

Respondents in a number of countries commented favorably on their affiliation with regional research networks. In small countries it is extremely difficult to mount and sustain a research program on a specific commodity at anything approaching the minimal desired level. However, by affiliating the program with a number of others, a small nation can specialize on aspects of particular relevance to that country. By interchange with the other members, findings applicable to other issues can be drawn from neighbouring countries. Membership in a research network raises the professional status and motivation of national researchers, and makes small programs more productive than they would be, were each to operate in isolation. The networks are perceived also to provide a mechanism for the research needs of the member countries to be reflected in the priorities of participating centers.

A number of centers recently have extended their networking to include specialists working with women in food production. IITA has begun to assist the African Home Economics Association to develop improved access to

agricultural research and its links with international fellowship programmes for female agricultural researchers. IRRI has taken the initiative in preparing for the inclusion of Women in Rice Farming Systems in the Asian Cropping Systems Network.

4.2.7 Matching of partner institutions and center programs

A necessary but not a sufficient condition for successful collaboration is the existence of two parties. In many cases of attempted center contacts, this situation did not always prevail. Particularly in the early days of the system, national programs dealing specifically with research on food production often did not exist, especially for the long-neglected root crops. The centers, in beginning their collaborative arrangements, had to seek out, often at their own initiative, those parts of national research systems which lend themselves to the best opportunity for development in what, from the centers' point of view, appeared to be an appropriate direction. An index of the centers' success in this regard is the widespread prevalence today of programs directed to enhancing national food production. Collaboration is, however, still not easy in some countries because of the state of the national research system. Respondents in several countries (Nepal and Ethiopia, for example) argued that, until the national research and extension programs are significantly strengthened, it will be difficult for center-based assistance to have much effect.

Stable funding and a low turnover of scientists create conditions favorable for collaborative work with the centers. In Chile a system of competitive grants operates for much of the agricultural research carried out

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in the relatively strong academic faculties of agriculture. In fact, the staff resource and research expenditures of the faculties represent close to half of the total agricultural research effort in Chile. While the funding system ensures well-targeted high quality research on specific projects, it does not guarantee a sustained level of funding in a particular area or for a given commodity. This factor limits the development of collaborative links between the centers and university researchers. Conversely, however, where collaboration with the centers can be shown to make local research efforts more productive, it can lead to additional support for such projects. The lack of contact the centers have had with universities and institutes outside the ministry is seen as a weakness of their links with Chile. In Thailand, the same point about general lack of contact between centers and university staff was mentioned as a problem that could readily be overcome to yield benefits to all concerned.

In numerous countries a significant and increasing amount of research takes place outside the formal public sector agency, which is usually within the ministry of agriculture. Universities, private firms, private research agencies and producer bodies may all have a role, and effective collaboration with a country can depend on a center establishing a number of links. For example, in Costa Rica the National Chamber for Basic Grains undertakes research and extension and is eager to collaborate with the centers, and private seed producers would like closer contact with and the opportunity to acquire genetic materials directly from the centers.

4.2.8 CGIAR versus other forms of assistance

With the piecemeal evolution of the CGIAR and other forms of donor assistance, the lack of an overall plan surely means that the present degree of coverage is necessarily less than optimal. Just what concept of optimality is relevant is not immediately obvious nor, as various observers who have thought of it have experienced, even very clear after periods of sustained contemplation. Some of the issues are the subject of the contemporary TAC consideration of long-term strategic priorities and further studies of the future evolution of the system. It is thus not surprising that many of the people interviewed in the developing world had comments about the coverage of the present CGIAR centers as well as the complementary activities of other agencies.

FAO has a wide coverage of developing countries through its system of representatives and special project activities around the world. Very few of these, however, have primarily a research focus. The CGIAR activities complement such development-oriented activities and, indeed, herein lies part of the rationale for FAO's co-sponsorship of the Consultative Group.

In recent times, many other donors have engaged actively in research and development programs that have a significant element of research. The World Bank has done this increasingly over recent years, and European and N. American donors have a long history of active work in many countries. Sometimes these programs invoke the direct collaboration with the centers in their association with their partners in developing countries. For example,

the program being implemented by the International Agricultural Development Service in Nepal on behalf of USAID and the government of Nepal, involves the interaction of center staff with the several national programs, particularly dealing with rice, wheat and maize. The support of the Cono Sun project by the Inter-American Development Bank involves the collaboration of center staff.

Considerable bilateral support has been given to Colombian research under Canadian, French, Dutch, German and British programs. The Colombians view these as valuable because of their focus on solving a specific problem in Colombia where the results and the knowledge remain. In contrast, the centers are seen as more ephemerally working on "world food production" with their activities less closely targeted to the needs of Colombia. However, the continuing and sustained presence of the centers, in contrast to the limited life of most bilateral efforts, is seen as a valuable feature. The high turnover of the staff in some bilateral programs and the tendency of some to use project work as training for students from the donor country tend to limit their value in the eyes of observers in partner countries.

The bilateral and multilateral agencies in Colombia can and do use their knowledge and contacts to act as brokers between the centers and national researchers. The support of IDRC for the potato research network, and its catalytic role in bringing CIAT's expertise in tropical pastures to bear on national problems were cited.

From the viewpoint of the donor community, a question of immediate relevance is how best to distribute resources between bilateral projects and contributions to the Consultative Group. This is a question of continuing review and requires some juggling of political consideration, as well as those of direct assessment of the effectiveness with which research can be implemented. In general, there was an enthusiastic endorsement by recipients of centers' contributions in relation to continuity, consistency and essentiality, vis-a-vis other forms of bilateral assistance.

4.3 Gaps in CGIAR Coverage

4.3.1 Gaps in geographic coverage

The domain in which the CGIAR centers presently work is now very considerable (chapter 2). It is not entirely comprehensive of the developing world, although the recent arrangements into which most of the centers have entered with China have considerably rectified the situation compared to that prevailing a few years ago.

The more overt gaps in coverage are functions primarily of the difficulties that lead to inopportune working arrangements in particular countries. Witness the aborted plans to establish one of ICARDA's headquarters in Iran, for example. Other parts of the world that are presently troubled by revolutions, wars and other human-inspired catastrophies similarly make collaboration difficult or impossible in the short run. CIMMYT activities in Nicaragua have recently been reactivated partly as a result of

some of the field work for this study. Several centers have also developed effective working relationships with Vietnam, Cuba, Angola and Uganda where previously local circumstances had impuded interaction. The centers seem well aware of the urgency of getting effective programs launched in areas that are currently serviced only spasmodically.

4.3.2 Gaps in commodity coverage

Most of the major food crops of the developing world are now encompassed within CGIAR institutional arrangements. Some of the commodities not yet within the system, but at least being addressed on the periphery, are vegetable production in general and, although the activities of AVRDC are quite wide ranging, this is still a somewhat neglected field in many parts of the world, particularly for those who find it difficult to work closely with AVRDC. Other food crops being brought into international perspective include bananas and plantains, and more comprehensive work on sweet potatoes. Other small, specialty items of food that are important in some countries are yet to be addressed through international endeavors.

Notwithstanding the continued investment in many national programs on research on export crops, the main perceived gaps brought to the attention of the study concern commodities beyond major food crops including industrial crops or export crops; fibers such as cotton, jute and kenaf, oil crops such as coconut and palm oil, and beverage crops such as tea, coffee and cocoa and pharmaceutical crops. The production of these commodities has traditionally

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been an important source of foreign exchange for many countries. Typically their research and development infrastructures have declined in the post-colonial era and in many tropical countries there are now perceived to be serious imbalances in the research infrastructure supporting such crops vis-a-vis those of more immediate interest to the CGIAR centers. Of course, any suggestions for expanding the commodity scope of the CGIAR must be considered against a backdrop of limited budgetery suport and the already long list of commodities and farming systems under study.

The Burmese, for example, would like to have more help on oilseeds and cotton. Burmese oilseeds researchers would like more contact with ICRISAT to supplement the assistance they have received thus far from a UNDP/FAO project which has brought in some groundnut germplasm from ICRISAT. They would also like assistance on their main oilseed crop - sesame - which is not covered by the centers. They have received some assistance on cotton from the UNDP/FAO project, particularly in the plant protection area. However, researchers expressed a wish for the type of assistance that the centers give.

Several African scientists hold the view that IITA and ILCA, the two major centers with headquarters in Africa, should have their mandates "reviewed and streamlined" if they are to impact more effectively on African technological problems. They also expressed concern that other centers with outreach programs in Africa had not reached the most effective ways of collaborating with African countries, although they noted with approval the establishment of the ICRISAT-led sorghum and millet improvement program in Southern Africa and the proposed CIMMYT-IITA mid-altitude maize testing station in the same region.

4.3.3 Other gaps

In the early years, the CGIAR focused on the production problems of field crops. Gardening systems have been largely ignored and, with a few exceptions, post-harvest operations through to the point of consumption have received little attention, although it is beginning to be recognized by the centers that the technical and market demands of both industrial and domestic processing, storage, and preparation of food crops are an important influence on varietal choice and preferred crop characteristics. Home economics services and appropriate technology centers have made advances in these two areas but the CG centers have been poorly linked to these kinds of institutions in the past.

4.3.4 Study team's views on gaps

The following three paragraphs are comments of the study team on matters raised by respondents in various countries.

Issues that need to be considered in investing in tree-crop research have not always been given due attention. First, quite apart from commodities like fruit trees and bees, many resource-poor farmers are involved in export crop industries so, while plantations may be major beneficiaries of research, such benefits may also be widely distributed to the most needy producers who rely on such crops for cash to supplement their subsistence food production. Second, tree crops may often play a crucial role in stabilizing resources, production and incomes in ecosystems that are inherently fragile. If productivity of tree crops can be enhanced relative to field crops, an

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important step towards enhanced ecological stability would be taken. The gestation period of research on tree crops is, unfortunately, long and there are needs for great patience and more challenging management and accountability of such long-term research.

The gaps perceived are especially significant since the comparative advantage that many countries once enjoyed in production of cash or export crops means that domestic agricultural resources can be much more efficiently devoted to their production than to some food crops. Institutions such as the World Bank now seem to perceive such an imbalance and a progressive rebuilding of research capacity, not necessarily through international centers but through reenhancement of national capacities, is in prospect in the future. There is, of course, a danger that the past relative neglect of basic food crops could be relived if there is an excessive swing of emphasis.

Very little research goes into aquatic resources, particularly fresh water fish farming, for example, and even less to farming of crustacians, molluscs, insects and fungi. The factors of production are dealt with in a still incomplete way through international initiatives. IFDC services fertilizer research. The new irrigation research center (IIMI) in Sri Lanka provides a significant beginning on much-needed irrigation research but this is still incompletely addressed because of the great diversity of related research issues, particularly regarding soil management problems in many places. Agricultural credit is a key input for most research implementation but this is not formally addressed although aspects of it have been tackled by the

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World Bank, and IMF and IFPRI research programs. ILO, UNRISD and the World Bank have studied labor markets but much yet remains to be done to understand this factor of production more insightfully.

Some respondents complained of the CGIAR neglect of animals and trees in many research programs on farming systems. Certainly there is very little attention to agro-forestry issues in the international sense (the exception being the small but significant program of ICRAF operated from Nairobi) and the CGIAR centers' work on animals is concentrated in Africa with only a residual program on pasture development now at CIAT. Thus the animal research needs of most of Asia, Latin America and, in fact, most of Africa must be met through national programs, supported by private-sector research and bilateral assistance in some countries. There are demonstrably many opportunities for technologicial development in the livestock and tree growing sectors of most countries and thus this omission is perceived to be a significant one in the current CGIAR portfolio.

4.4 Coda

* The initial contacts of researchers in many countries were with organisations antecedent to the centers, particularly with the Rockefeller Foundation program of technical assistance to selected countries in Latin America and Asia.

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* The establishment of IRRI and CIMMYT broadened the scope of contacts to a much wider range of countries. Establishment of additional centers further widened those contacts to include nearly all developing countries, but centers still focus on countries in which their mandate commodities are important.

* In most countries, export and cash crops still receive a higher proportion of the research budget than they contribute to the value of output even if the programs are perceived by some national observers to be run-down and ineffective. The Consultative Group and most of its centers exist because of a widely held perception that, hitherto, the biases of agricultural research were towards these export crops to the neglect of basic food crops.

* Respondents in Brazil, Bangladesh, India, Colombia, the Philippines, Mexico and Nepal mentioned some high-handed attitudes in earlier days of their associations with the centers.

* In more recent times, doubtless reflecting a degree of maturation on both sides of the collaborative arrangements, there have been seemingly much better relationships established. By and large, respondents were very positive about the quality of their professional association with colleagues in the centers.

* Comments by respondents in host countries typically reflected frustration with the CGIAR centers' focus on world or regional responsibilities rather than on the range of problems most pressing to the host country. This is

surely inevitable given the centers' international responsibility in their mandates, and the requirement of the host country national program to cover a broad range of locational specific agricultural research issues.

* Respondents cited continuity of association as being very important in successful collaborative research. Consistency is another positive feature often emphasized. In general, there was an enthusiastic endorsement of centers' contributions in relation to continuity, consistency and essentiality, vis-a-vis other forms of bilateral assistance.

* The alternatives for providing genetic resource exchanges of the type offered by the centers are generally not extensive. Indeed, the very existence of the centers in most cases is to fill a gap that donors and others have detected in institutional arrangements in the world.

* Respondents in a number of countries commented favorably on their affiliation with regional research networks.

* In general, national researchers consider that the workshops, conferences, training opportunities, newsletters and publications from the centers are more important to their work than similar services obtained from other sources.

* In the early days of the system, national programs dealing specifically with research on food production often did not exist, especially for long-neglected root crops.

* The lack of contact the centers have had with universities and institutes outside the agricultural ministry is seen as a weakness of their links with Chile. In Thailand, the same point about general lack of contact between centers and university staff was mentioned as a problem.

* The main gaps that have been brought to recent attention concern commodities beyond the major food crops. These include industrial and export crops; fibres such as cotton, jute and kenaf, oil crops such as copra and palm oil, and beverage crops such as tea, coffee and cocoa. While plantations may be major beneficiaries of research, such benefits may also go to these resource-poor producers who rely these crops for cash to supplement their subsistence food production. Needless to say, the issues raised by these national perceptions of coverage are complex, and debate over future policy must range over the extent of resources available through the CGIAR, problems of accountability in research on long-cycle tree crops and the danger of moving full circle to a new era of relative neglect of basic food crops.

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5 NATIONAL VIEWS OF CENTER ACTIVITIES

5.1 Introduction

The structure of this compilation of views on the contributions of the centers reflects their major products. The first considered is the arguably most important provision of plant genetic material. This is followed by views on methods, training, institutions and last, but certainly not least, policy work.

5.2 Views on Genetic Materials

The centers concerned with plant improvement have given high priority to providing national collaborators with pools of genetic materials of interesting diversity, and selected materials that have proved to be useful in some important environments. Provision of such material gives plant breeders a great start in their search for variation to incorporate in their own crop selection programs. In extreme cases, people can merely select amongst the materials with which they are provided. In every country study, the provision of germplasm of important food crops was most frequently cited, along with training, as the most valuable contribution of the centers.

5.2.1 Early contributions of the centers

Asian rice breeders active in the early 1960s agree that the major single contribution injected through IRRI's catalytic role was dwarfness. The rice research programs of Asia had taken well the lessons from Japan, Taiwan, and Korea that fertilizer-responsive varieties could raise yields. Under the auspices of the FAO, they started the Japonica-Indica crossing program which aimed to develop varieties that were responsive to fertilizer. However, scientists in both the Indian and Philippine systems stated that the idea of using dwarfness to get the fertilizer responsiveness that they were seeking had not occurred to them. Breeders in India were not looking for dwarfness because they were not working on irrigated rice. Most Indian rice was grown with poor water control in the early 1960s and, under such conditions, dwarfness can lead to problems of submergence.

Scientists discussed the likely course of events if IRRI had not developed semi-dwarfs. There still would have been increased yields from rice varieties such as C4-63 in the Philippines, ADT-27 in India, and Mahsuri in Malaysia. These were lowland varieties like IR8, more resistant to lodging and more fertilizer-responsive than the old Indica varieties, but were taller, less resistant to lodging and less fertilizer responsive than IR8. They were also of higher eating (but the same nutritional) quality compared with the early IRRI varieties. These varieties probably would have spread more slowly than the semi-dwarf varieties but, even in competition with semi-dwarfs, they

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spread quite rapidly not only in the countries in which they were developed but also in Bangladesh where Mahsuri is still more widely used than any short IRRI or BRRI variety, in Burma where C4-63 is widely used, and in Indonesia.

Before the Mexican (INIA) wheats were tested, wheat breeders in India were already looking for fertilizer responsiveness and had access to USDA genetic material. In addition, at least one breeder had already written to Washington State University for some of the same semidwarf wheat genetic material that was used to produce the INIA and CIMMYT wheat varieties. However, the INIA varieties were discovered at the same time and so that line of breeding was dropped. Indian scientists familiar with this program suggest that the INIA varieties sped up the release of modern varieties by roughly five years in India. For other developing countries that did not have strong research systems at the time, incuding the rest of Asia and N. Africa, with the possible exception of Pakistan, modern wheats would have spread from India if at all.

The effect on research productivity of having germplasm available from the centers was discussed by plant breeders in the Philippines. Their 1960 germplasm collection consisted of locally collected varieties, some exotic lines from S.E. Asia, some material from the Indica-Japonica crossing program and a collection of about 2000 lines from the USDA which included some of the Ponlai varieties from Taiwan. This base enabled them to produce C4-63, a medium-tall variety, that was moderately responsive to fertilizer. It was released at about the same time as IR8 and was better suited to some areas

than the early IRRI varieties. Thus, even without IRRI semidwarfs, there would have been some increase in rice yields. The University of the Philippines rice breeder at the time stated that the value of IRRI was illustrated when both the local improved varieties and the IRRI varieties came down with tungro disease. The larger IRRI breeding and entomology programs had already identified resistant germplasm and had substitutes ready to be released for areas badly hit by the disease.

Even for rice and wheat, the differences between the old system and the current system of having germplasm available through the international nurseries are substantial. The rice collections consisted of those of USDA, the Japanese and several other large Asian collections. The USDA collection was available to a number of Asian breeders. Rice breeders could also write to the rice agronomist of the FAO for varieties. The one regionally coordinated rice project was the Indica-Japonica crossing program sponsored by FAO. It made some contribution in a number of countries, and several varieties from the program became important, but it was terminated before IRRI was founded. Since the development of international rice nurseries, plant breeders obtain germplasm routinely. They no longer have to write to the USDA or the FAO rice agronomist and describe their needs. Instead, there is a constant flow of the best rice material in the world, including material with known resistance to diseases, pests and adverse conditions.

Befre CIMMTY, wheat varieties were exchanged regularly between some countries. The USDA had rust nurseries in operation from the 1950s in India,

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Pakistan, Turkey, Mexico and other countries. However, countries with less developed research systems had little or no access to these sources until CIMMYT organized its international nurseries.

Similar conditions prevail for nearly every crop in which the centers work. Until CIAT and IITA began active provision of cassava clones, there was virtually no organized source for such materials. Seed potatoes could be obtained from commercial sources but, until CIP's program, there was no systematic way in which developing countries could obtain a selection of potato varieties likely to be superior for their environments. Extensive exchange of these and other vegetatively propagated root crops was enhanced by the development of disease-free propagation methods. International exchange of food legume seeds was a completely ad hoc activity until the international testing programs for field bean, cowpea, chickpea, pigeonpea, etc. were established.

The availability of the germplasm collections and networks has significantly raised the goals of research. In the Philippines, for example, the introduction of elite germplasm from the centers resulted in a substantial increases in yield potential. Such changes greatly broaden researchers' outlook and improve their perception of achievable goals. For example, elite maize and sorghum lines from CIMMYT and ICRISAT have helped to raise the yield expectations of plant breeders in the Philippines. For cassava, yields exceeding 40 t/ha were suddenly perceived to be achievable where 20 t/ha was previously regarded as excellent. Similar changes have been documented

relative to sweet potato, potato and grain legumes. Indian scientists also reported a similar important change in attitudes from a quest for gradual changes in yields to one for major increases.

5.2.2 Selective vs diverse materials

Plant breeding is an inherently risky business since the success of achieving new combinations of genetic material to produce superior cultivars is like a game of genetic roulette. The chances of success can be enhanced through good practice in plant breeding and selection techniques, but the uncertainty inherent in the whole process cannot be overstated.

Feelings about assistance in plant breeding programs from external sources are thus influenced to some extent by the good fortune or otherwise that individuals have experienced. The degree of success is a function of the serendipidity of the individual breeder, the extent and quality of resources the individual has to work with, and the success that the external source of assistance has had in assembling an appropriate portfolio of material. The international centers have usually adopted a strategy of deliberately including very diverse materials in nurseries so that there is a good chance that there is something within an international nursery or within supplied segregating materials that will be of interest for every important ecological niche.

There are conflicts implicit in this process. On the one hand, centers need to supply sufficient quantities of materials to boost the chances of detecting locally valuable materials. On the other hand, planting out and

managing nurseries and collections of germplasm is not a costless activity and can easily exceed the resources available for such work in some countries. To a certain extent, this problem depends on the size of a national program. In situations where there are few trained staff for plot management and very scarce physical resources for experiment stations, the successful conduct of large international nurseries can severely stretch national capabilities. This was specifically mentioned by researchers in Malawi with respect to maize, rice and sorghum and in Zimbabwe with respect to sorghum. However, too selective a policy is not appropriate in many cases.

Cuban scientists were concerned that the rice materials that they received from CIAT had been too closely selected for traits that were not necessarily relevant to Cuban circumstances. For example, if CIAT screened out all materials not resistant to a disease that is of minor importance in Cuba, this restricted the material sent to Cuba. As a consequence they felt that they were loosing the opportunity to examine a wider range of materials on which they might draw. They noted that the more diverse selections received from IRRI partly compensated for this. Similar arguments were used by Mexico and other countries urging centers to provide segregating materials (see chapter 6), given the capability of advanced national programs to evaluate and to incorporate such materials.

There is a danger that the particular needs and conditions of a country may not be fully appreciated by center researchers. Thus, on a very detailed and specific request to IITA for rice varieties, an agronomist in Zimbabwe

received 80 varieties which, in good faith, he incorporated into detailed observation trials at three sites. The majority of the varieties performed very poorly and, after subsequent correspondence, the breeder learned that only half a dozen of the varieties sent actually had the characteristics originally requested. Researchers in Malawi, in contrast, reported that IITA's short involvement with them on rice had been exemplary.

Another positive counter-example, in this respect, is Malawi's collaboration with CIAT. The center continues to respond to the country's requests for bean material in a most specific manner. Thus the country receives material specified according to request by seed color and size, disease resistance, growth habit and the like. Malawi's progress in bean breeding has been particularly rapid because of the intensive interaction with the center.

The "burden" of international nursery trials is perceived as even greater when the results of the tests are not or too slowly made known to the field-level researchers responsible for conducting the trials. Mexican scientists urged the centers to make more effort to ensure that the results get to field-level staff, a task made even more important, albeit difficult, by the high rate of turnover of the Mexican staff.

In such an inherently uncertain business, perhaps there will always be a less than perfectly satisfactory solution for such widespread sharing of internationally assembled germplasm.

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5.2.3 Other material assistance

By and large, the centers have not been in the business of supplying many materials other than plant genetic resources to their partners. The main flow of other materials to some partner countries has been restricted to investment in research facilities in countries that are hosts to centers and major center outreach programs. An exception is the assistance provided by IBPGR in its work with national programs and universities to collect germplasm in a wide range of crops (e.g., Peru and Ecuador in the Andean zone).

The centers have often proved to be very helpful to individuals at research stations in national systems by supplying key factors that help to achieve success in research. Kenyan researchers reported their appreciation of timely financial assistance from CIP for minor but critical expenses. CIMMYT has also been mentioned as providing small pieces of equipment. IITA provided the plant quarantine station with a small grant to improve the facilities for tissue culture and field conservation.

Shortages of foreign exchange cause perennial difficulties, and resources to purchase expensive scientific equipment are frequently difficult to find. Some bilateral donors are very important in particular situations in filling some of these gaps, and centers often work cooperatively with such donors to help to identify those of the greatest priority. Center staff posted to national programs under special projects make small but strategically very important outlays of cash and other resources to help meet particularly urgent needs. Sometimes these needs are as simple as assisting with local

transportation arrangements. In other cases, it may amount to financial assistance for chemicals and other materials that otherwise may be very difficult for the individuals concerned to acquire. In Ecuador, for example, various programs have benefited from and really appreciated the direct assistance of the centers in such seemingly trivial transfers as the inclusion with seeds of identification cards and covering bags for crossing. Similar assistance was mentioned in Burma, Indonesia, Peru, Syria and other countries.

In summary, while material assistance may be modest in most cases, it is widely appreciated by national scientists who, in the interviews in the country case studies, often expressed their appreciation of it.

5.3 Views on Methods

5.3.1 Plant breeding techniques

In retrospect, it is widely perceived that the novel twist of the early successes in otherwise rather conventional breeding of wheat and rice was the quest for wide adaptability, daylight insensitivity, and a changed crop architecture to give high yields through intensive use of complementary factors of production such as fertilizer and irrigation water. Resistance to the main diseases of wheat and rice was of central importance from the beginning, but insect resistance emerged as a breeding objective at IRRI only after about five years of work. Reduced growth duration was the third major goal of the breeding programs. It facilitates increased cropping intensity. Programs for other crops have to a greater or lesser extent had similar goals. The breeding approaches of the centers are subject to some critical appraisal in chapter 6.

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Plant breeding techniques can be approached at several levels. At the lowest are the mechanics of effectively performing crosses in a crop, then come screening and selection, methods for maintaining pedigree nurseries or populations and, perhaps at the highest level, come breeding strategies.

Centers have been quite successful in passing on skills and techniques. In wheat breeding, for example, there is a definite technological challenge in mastering the physical skills of making crosses. The center-trained plant breeders interviewed in this study were generally very appreciative of their experiences at the centers in improving their own techniques, learning procedures for monitoring nurseries and making selections, and of any active assistance from center breeders at key times in their selection work. Being able to discuss their specific objectives and criteria for selection in the field with somebody they respect and can rely on for relevant knowledge is a great advantage and is widely valued.

Examples of techniques learned from centers abound. Researchers in Kenya cited the techniques for mass rearing of hoppers and maize borers for artificial inoculation of maize in screening for resistance to maize streak virus and maize stalk borers. They also mentioned techniques for gathering and storing wheat rust inoculum to ensure a high level of disease pressure in nurseries.

Philippines researchers mentioned techniques for evaluating disease resistance in sorghum developed at ICRISAT, for evaluating rice blast resistance developed at IRRI, for rearing corn borer developed at CIMMYT, and for evaluating high-lysine maize designed by CIMMYT.

Population breeding--although not originated by the centers--has been popularized by CIMMYT for maize and by ICRISAT for sorghum. Those techniques are now being widely used. The populations developed at the centers are often used as the starting point by national programs.

Breeders in Burma, Indonesia and Bangladesh cited the spikelet-clipping vacuum emasculation technique for simplifying cross pollination in rice as an important technique. With this technique, a person easily makes 50 crosses in a day. Although IRRI is not the originator of this technique, it has so perfected it and has demonstrated it to so many local breeders that it is currently the standard emasculation method used in many countries. Breeders in Burma also adopted the use of shorter rows in growing out segregating materials, the practice of retaining more variability from one generation to the next, and modified their practice as to in which generations selection for various characteristics are made.

In India, Indonesia, the Philippines, Bangladesh, Guatemala, Egypt and Cuba, breeders indicated that interaction with several centers has fostered the development of an interdisciplinary approach to plant breeding. Instead of the breeder doing the breeding, and the entomologist and pathologist

separately evaluating the varieties produced, the three now work together from the beginning of the breeding program to incorporate multiple resistances.

Indian and other researchers mentioned that ICRISAT has improved methods for screening sorghum germplasm against grain mold, downy mildew, striga and midge. The checker-board technique for testing sorghum lines against striga resistance is being used now by many national researchers. The method of screening sorghum lines against midge is considered a definite improvement over earlier approaches. Large-scale field screening techniques for pearl millet have been developed and used to screen for downy mildew, ergot and smut in one and the same generation.

ICRISAT has demonstrated that the wilt disease of chickpea, which baffled Indian pathologists for over 40 years, is incited by a number of pathogens. Screening methods have been developed and sources of resistance found for many of the pathogens and environmental stresses that prevail in India for both chickpea and pigeonpea.

Techniques developed by IITA for rapid vegetative propagation of cassava were reportedly adopted by researchers in Kenya. Similar rapid vegetative propagation techniques for potato were adapted from CIP activities by researchers in Bangladesh, Rwanda and Vietnam.

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Researchers in Chile reported an important contribution by CIAT in methodology for pasture evaluation, despite the fact that tropical pastures are not used in Chile. The evaluation methods are transferable and are being used by the national program in other agricological work.

5.3.2 Agronomy and farming systems

The scope of agronomy is so wide that generalization of views on agronomic research methods is correspondingly difficult. Farming systems research has had many important instigators but few as significant as the centers in advancing the cause of "farming systems" thinking in developing countries. The semantics of these activities are elaborated in chapter 16. Agronomists in the centers have professional interactions with a wide variety of researchers ranging over disciplines as diverse as plant pathology, entomology, general agronomy, soil science, and so on. Plant physiology has been a rather controversial issue amongst centers and this discipline is somewhat under-represented both in the centers themselves and in the national programs.

The impact of much of centers agronomic thinking is transmitted through the production training courses that are run at centers; these are covered in the more general views in the next major section of this chapter. As important as agronomic work is to increasing productivity, from farming systems work, it was seldom reported on by national researchers separately aside.

Semantics aside, the central theme of all farming systems research activities is sufficiently uniform to allow some generalization. The impact on thinking of national researchers has been constrained by the rather slow institutional development surrounding farming systems research. Many countries have now instigated farming systems research programs, largely at the behest of donors, often with the assistance or encouragement of the centers, also, according to themselves, because research planners have been sufficiently impressed by the idea. Where such innovations have been enshrined in bureaucratic structures, cooperation of the centers with the national programs is straightforward. When this is not the case, which is the situation in most countries, implementation is rather more challenging. A section of a national commodity program is then the usual focus of collaboration.

Chilean wheat researchers report an important contribution by CIMMYT in the area of agronomic practices and the development of production systems for Chilean wheat. This reflected the work of a resident CIMMYT scientist and the ideas and methods suggested by visiting staff. An innovative project along these lines started at the Guilamapu Station in 1978. By combining local results on wheat and legume varieties, fertilizer use and weed control into a systems approach, wheat yields on farms have risen three fold in the dry coastal areas of the central valley. This approach to research has opened a new and promising field within the national program.

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Participants in the Asian cropping systems work initiated by IRRI have been encouraged to take a broad view of the role of other crops in rice-based cropping systems. In the study team's view, a difficulty until recent times has been the rather circumscribed view of farming systems taken, confining the research thrusts only to crops and intercrop competition. Recently, desirable extensions of the approach have been made to include other important elements such as livestock and trees. The enthusiasm observed among the multi-disciplinary cropping systems researchers in, say, Bangladesh, was remarkable.

National scientists, overcoming their confusion about the somewhat diverse advice received from centers and other external sources, are rapidly coming to appreciate the significance of a farming systems perspective in addressing their research problems. Among countries visited, farming systems approaches were specifically appreciated by researchers in Bangladesh, India, the Philippines, Nepal, Indonesia and Panama. The particular value of this approach for smallholder research was mentioned by respondents in Kenya, Zimbabwe and Malawi.

CIMMYT's involvement in Malawi has been instrumental in establishing adaptive research - a farming systems approach. Ready access by the national program to training courses from CIMMYT's regional E. Africa office was a key element in this. Ecuadorian researchers also mentioned the assistance that CIMMYT provided to help them to establish a series of production research programs as an institutional strategy to ensure consistency between the generation of technology and the circumstances of representative farmers.

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5.4 Views of Enhancement of Human Capital

5.4.1 Formal training programs

As noted, germplasm and training are considered by the national programs to be the most important contributions of the centers. A detailed description of center training programs is given in chapter 9 along with a distillation of views held by trainees from the recent TAC study of training.

Most of the individuals who reported having had training experiences at the centers were positive about them. The highlights mentioned were the opportunity to see how an international center operates and to participate in some of the research activities. They valued their chance to visit a different country and to see how things are done. They also greatly valued the opportunity to mix with their colleagues from several other countries engaged in the same training, thereby forming a basis for subsequent contacts.

Some, however, expressed reservations about the training. Given the diversity of backgrounds of the trainees, the countries and the disciplines that are broached simultaneously, there is a significant difficulty in matching training experiences with the particular needs of individuals. This difficulty is reflected in some stern judgments as to the quality of some training programs - usually that they were pitched at too low a level. The match was simply not very good in some cases.

Since the mid 1970s, Brazil has had a rapid and substantial rise in agricultural research expenditures as a result of the formation of EMBRAPA. Much emphasis was given to training. In 1976, over 60 percent of EMBRAPA's researchers held a bachelor degree as their highest qualification. Today over 80 percent have master's or PhD degrees. This has important implications for the nature of training that Brazil would like to see offered by the centers. Courses in production methods served a useful purpose in earlier years, especially in the newly created bean and cassava programs where there was little or no local history of research. The opinion was given that most of the courses offered by the centers are now of limited interest to the Brazilians, given the much higher qualifications of their research staff. They would prefer to see more emphasis on research methods. Furthermore, greater advance notice of courses and the number of places available would help the Brazilians (and others) in their planning.

Researchers at University of the Philippines at Los Banos rated germplasm as the most important service received from the centers, but researchers at the smaller regional research centers in the Philippines such as Southern Mindinao University, Maligaya Research and Training Center and Camaranes Sur Agricultural College rated training as the most imporpant function of the centers. These institutes also felt that the regular visits from center staff were important as a source of information on new research findings and of opportunities for training.

Researchers in Kenya indicated that the various courses offered by the centers were particularly beneficial for the technical cadres and first-degree holders. They also observed, however, that some courses were too general, lacked depth and failed to discriminate sufficiently among those admitted on the basis of educational background.

The Peruvian program expects to depend heavily on the training offered by the centers as a way of rapidly rebuilding its stock of human capital in research, which was left badly debilitated by the institutional and political changes of the 1970s.

Cuba plans to expand its numbers of research scientists by over 50 percent in the next five years. Most of the degree training will be done at Cuban universities with some specialized training in basic sciences undertaken in universities and research institutes in E. Europe. However, the Cubans expect to rely heavily on the centers that offer training in tropical agronomy which otherwise is not available to them.

The Syrians attribute an important part of their success in cereal improvement to the long-standing and regular participation of their research staff (SARD) in CIMMYT training programs. Training on a larger scale is also an important contribution by ICARDA whose activities in this regard are reported to have led to the establishment of two new departments within the field crops section of SARD. Indeed, the Syrians are looking to the centers

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in general to assist with much needed training across the complete spectrum of professional activities in the national, presently uncoordinated, research institutions. The call, as in so many other countries, is especially for formal postgraduate work.

Training courses conducted in their home countries were rated as particularly useful by researchers in Ecuador, Malawi, Zimbabwe, Cuba, and a number of other countries. The active participation of a wide range of scientists from CIAT was deemed highly productive in the cassava training courses conducted in Cuba.

Collaborative research activities contribute strongly to human capital enhancement and are an especially important means by which IFPRI assists in national research. A current project with a University and the National Council for Science and Technology of Kenya was warmly viewed by researchers there.

5.4.2 Communications, newsletters and networks

Considerable investment is being made by the centers in a diverse range of communication activities. These include newsletters reporting network activities (see chapters 2 and 10) or dealing with crop improvement, systems for providing access to expensive foreign research journals, scientific working papers. and annual reports of the centers. The audience for center publication is also diverse but most publications are addressed explicitly to colleagues in partner countries while others are perceived by these recipients as being intended more for donors.

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The systems of Selective Dissemination of Information (CIAT, IITA, ILCA and ICRISAT have such projects stimulated by IDRC initiatives and grants) eliminate many of the immediate costs of access to contemporary world literature. As pointed out by many crop and livestock researchers, especially in Africa, most journals must be purchased in foreign exchange that is extremely scarce in systems with stretched recurrent budgets. After pertinent information is identified copies of the selected material are provided upon request.

Most centers compile extensive bibliographies of current literature in their mandate fields and make these, as well as reprints of articles, available to national researchers - usually for free but in some cases of published book formats for sale. Some centers have made major original contributions to the development of information systems while others have enhanced systems already in place, such as those of the Commonwealth Agricultural Bureau (UK).

Some scientists felt that the nature of the services of the centers was not widely enough known and understood, and that more promotion and information is needed. However, many, including some from Mexico, Malawi and Zimbabwe, were concerned that the publications that they received were often too general to be of use in their scientific endeavors. As opposed to receiving public-relations-type publications, they expressed a need for more technical bulletins with details on materials, research methods, and research findings. Shortage of funds often precludes, their purchase of the increasing

number of books that contain the more technical research findings of the centers. The need for publications to be in Spanish if the centers wish to reach a wide audience of scientists in Latin America was reiterated; a parallel need exists with French in W. Africa, with Arabic in the N. Africa and the Middle East, and presumably with Chinese.

In Indonesia and Malawi, the quality of publications from the centers was praised but not their distribution. There was concern that, while national policy makers and presumably donors need to have information on center activities, the more technical reports were seen as being more useful in the hands of research workers who badly need them yet, especially those away from the main center, have very poor access to such material. The centers need to take more note of the difficulties in order to design appropriate strategies.

5.4.3 Informal enrichment of experience

While most of the centers' resources concerned with human capital enhancement are devoted to relatively formal modes of assisting individuals in their personal development, informal means are also used. A good example is the tour of agricultural development projects and agencies in the Philippines and Japan arranged by IRRI for senior Bangladesh agricultural officials. Similar study visits are a regular part of CIAT's Central American bean network and CIP's potato network. These activities are difficult to evaluate in terms of impact, but the individuals concerned reported on their effectiveness in expanding the horizons of people who hitherto had very circumscribed opportunities to view developments outside their immediate spheres of activity.

The same principle applies to people at all levels of research systems. The idea of broadening rather restricted educational opportunities through tailored travel to particularly innovative and successful examples of agricultural development is one that is actively pursued through a number of centers. Even in the more formal training programs, there is significant educational advantage to recipients by temporary relocation in a different culture with different methods and approaches being demonstrated. The centers are one important instrument for facilitating such international extension of different ways of thinking about agricultural development work. The UN agencies are, of course, very active in such work, as are universities everywhere that teach foreign students. The advantage of the centers, according to many respondents, is that they provide trainees with an opportunity actually to carry out relevant agricultural research activities, rather than just to hear about them. Centers, in principle, are usually fairly well equipped to offer a program that permits each person to master research techniques well targeted to individual needs and aspirations.

Informal training also occurs when scientists from national programs visit researchers at the centers. This has been an important activity at IFPRI and IRRI. Increasingly the publications of the centers (e.g., IFPRI's Research Reports and CIMMYT's training manuals, one of which has gone to 15,000 people, are being used as teaching materials in universities in developing countries, expanding the indirect role of the centers in training.

Needless to say, any formal evaluation of these special means of enhancing human capital is beyond the resources of the present investigators, but should not be ignored merely because of the difficulties in measurement. Whether or not the system of international centers is needed to achieve such objectives is another matter but, since they do exist and work so effectively, their contribution is not to be taken lightly.

5.4.4 Post-doctoral and other modes of service

Most of the centers have programs under which researchers from partner countries spend one or two years at the center headquarters in post-doctoral positions. Both participants and centers consider these to be more than training appointments but they do enrich human capital. Researchers in India, Bangladesh and Indonesia mentioned post-doctoral appointments as valuable opportunities. Some controversy exists about the practice of some centers in having more than one level of post-doctoral appointment, and some questions were raised about having individuals from industrial countries appointed to these positions. There was a strong expression of demand for more post-doctoral opportunities from researchers in Indonesia, Bangladesh and other countries.

One form of training that is not always recognized as such within the centers is service on the staff of centers by professionals from partner countries. The centers vary in the intensity of hiring of professionals from developing countries, but just over half of all senior international center

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staff are, indeed, from those countries (chapter 2). This is a rather different form of human capital enhancement that may not always be directly exploitable within the country of origin of the people concerned. There have been several instances, however, of professionals serving a term on the staff and then returning to their national programs. Clearly they bring with them a greatly heightened sense of possibilities from the perspective of their international experiences. Others go on to other employment outside their country and thus may be effectively lost to the national service.

There are two sides to this. One feature evident at the moment is that the turnover rates of staff in the international centers vary considerably by country of origin. It is clear that personnel from most of the developing countries tend to stay for rather longer periods of service with the centers. There are several explanations of this. One is the difficulty of individuals finding suitable positions back in their national systems after being "out" for several years. People in several countries rate this as an issue for the centers and national programs both to consider. Various suggestions were made for fixed term appointments of international staff so that all staff would be obliged to retire after some maximal period (say, seven years). If this was institutionalized more formally, it may well be possible for researchers to negotiate return to designated points in national programs without the disadvantages that are presently associated with discontinuous service in hierarchial systems where promotion is by seniority in service rather than achievement.

5.4.5 Graduate training

The centers have done much to strengthen some of the major agricultural universities in Asia. The ability of more collaboration to strengthen agricultural universities - particularly those drawing students from several countries in a region - was raised in many countries. The Rockefeller/CIMMYT maize program with close ties to Kasetsart University in Thailand, was said to have significantly improved research capacity.

Bangladesh researchers desired more opportunities for university faculty to participate in the center training activities. This was needed both to upgrade their research skills, and to train the trainers of new researchers, technicians and extension personnel. There is some frustration with the constraints on center training programs that seemingly prevent scholarships from being used for this purpose at present.

IRRI and the University of the Philippines at Los Banos (UPLB) appear to have had a mutually beneficial relationship. UPLB receives the same services as other research systems but enjoys some additional advantages. IRRI staff teach a few courses and advise many graduate students, both those on IRRI fellowships and others. Graduate students and faculty use IRRI facilities. There is personal interaction between agricultural scientists and economists of the two institutions. The major negative effect of IRRI activities mentioned by respondents was the decline of the UPLB rice research program which some feel needs to be strengthened to train the rice scientists of tomorrow.

UPLB staff pointed out that IRRI has benefited from the connection with UPLB. IRRI has access to UPLB graduate students who do research at IRRI relatively cheaply. They are able to place master's and PhD students from other countries at UPLB on IRRI fellowships but, since university fees do not cover full costs, there is some an element of subsidy. IRRI has also hired several excellent staff members from UPLB. An analogous relationship exists between IITA and the University of Ibadan. Many trainees at IITA are registered for higher degrees at the University of Ibadan and are jointly supervised. The Faculty of Agriculture of the University of Benin, Cotonou and IITA also have a similar relationship.

Quite a few respondents challenged the centers to "provide" greater numbers of post-graduate scholarships and center research opportunities. It must be observed here that the centers have only limited resources to serve these demands, and since they are not grant-making institutions, simply do not have the funds greatly to extend their post-graduate training sponsorship. There are many universities in industrial countries that have programs for developing country students, but the research component of such post-graduate degrees is not always ideally tuned to the needs of scholars from partner countries. An expansion of donor resources to support center-based thesis research opportunities for students taking degrees at advanced universities is one alternative that was often suggested to the study.

For the long run, it should be observed, the real challenge is to build developing country universities in a manner to address these needs. This will not be easy and will take a long time. Sensitivity to the problems involved

in building such domestic capability will be required and nations and donors must be prepared to wait, possibly decades, for the rewards from such investments.

Some observers in the discussions conducted in this study went so far as to suggest that there should be a new CGIAR center with a title something like the International Center for Agricultural Research Education, which could address the research training needs on a global basis and take some of the responsibilities of such activities from the present centers. Meantime ISNAR in particular, and in various ways most other centers to some extent, do the best that they can to assist countries in meeting these needs.

5.5 Views on Institutional Change

5.5.1 The centers as models

Several national programs have been closely modeled after a center. In these cases, the model can be a most significant impact on the structure of national agricultural research systems. Some countries have pursued this approach to a very considerable extent, for example Brazil (see chapter 10). Others have taken the center model as the basis for a national commodity program, for example the Bangladesh Rice Research Institute whose structure and organization, including its mission-oriented departments, are very similar to those of IRRI.

The newly reorganized Peruvian system is structured around commodity programs reflecting an influence of the centers. Furthermore, the centers concerned have nominated co-leaders of each of these programs ensuring an effective flow of information between the centers and the Peruvian scientists. Other countries have copied various parts of the centers, and many of the organizational reforms introduced into the national agricultural systems can be traced in part to the influence of the international agricultural research centers. Farming systems research programs are a prominent example of this tendency.

5.5.2 Influence of the centers on levels of investment in research

As has been noted in other chapters, the green revolution and its accompanying publicity was credited by many research workers as having been important in increasing the level of investment in agricultural research. For example, the head of the Agricultural Corporation in Burma reported that it was the success of the Whole Township Rice Program, which was based on IRRI varieties, that was largely responsible for the recent expansion of agricultural research in Burma.

Sometimes the existence of collaborative arrangements with the centers serves to protect the budget of parts of a national program in times of fiscal stringency. The stability of funding can often be as critical as the absolute level of support in maintaining a viable research effort. Researchers in Malawi noted that visiting scientists often have access to and influence with

research directors and political leaders, and can help in securing funding for national programs.

Malawi's cassava program is an example of how collaboration by an international center can work in creating a sound local research program. After contact between IITA and the Malawi Government, the national research system was persuaded to start a research program on cassava. A member of staff was sent to IITA for a "root and tuber" production course in 1978. The breeder admits that he went with no idea about these crops and returned dedicated to them. He was encouraged by IITA staff to start first a collection of local varieties of cassava and sweet potatoes. This collection has identified some good local lines of cassava that have been released to farmers and successfully adopted. The breeder maintains close contact with various extension staff and again attributes this orientation to IITA training. The program has been thoroughly supported by IITA.

Research administrators in several institutions told the study reporters how they had used the presence of the centers or center activities to lever more resources from their governments. Several senior scientists at the University of the Philippines at Los Banos recalled that, in the early 1960s, the Dean of the University made contact with the World Bank about a loan for a major building program through the Director of IRRI. He was also able to use the existence of IRRI as a point in discussion with Philippine legislators for counterpart funds needed to match the Bank's support. All five of the Philippine research institutes visited in this study were running CGIAR center cooperative trials, and reported that they received additional resources from

was instrumental in the creation of a small cassava material program. The productive collaboration between CIAT and the Cuban center for root crop research, together with the concomitant increases in farm production, was said there to have stimulated greater Cuban investment in cassava research.

The production of IR8 varieties shifted the attention of most rice breeders during the 1960s. In the Philippines, the rice research program at UPLB decided to let IRRI conduct the lowland irrigated rice research while the University would undertake the research on upland rice. Again, when establishing the Institute of Plant Breeding at the University, it was decided not to do any research on rice because of IRRI's presence, but rather, because of the weakness of research on other crops, to concentrate on them. In recent years, as other crop research has gained in strength, national researchers have been asking for UPLB and the Bureau of Plant Industry to do more research on rice, and IRRI also has been encouraging the strengthening of the program.

Burmese maize breeders changed from breeding inbred lines for hybrids to the CIMMYT methods for developing composites of open pollenated populations. Agricultural engineers at the Agricultural Research Institute at Yezin (Burma) shifted their priorities from tractor-drawn implements to bullock-drawn and hand implements after the arrival of the IRRI team. Burmese rice researchers had been concentrating on improved management because they assumed that only small yield increases could come from varieties, until they imported IR8. It was not directly successful but it showed the potential for improvement through rice breeding. As a result, the Burmese shifted some resources from the IRRI nurseries, but also through mutation breeding and crossing.

5.5.4 Advice on institution building and research organization

National agencies and authorities can be more or less receptive to advice on how their institutions may best be organized or reorganized. Since the early centers began their work, there has been considerable direct and indirect advice from center staff on many aspects of organization for research. Institutional structure has often been influenced but, perhaps even more importantly, the style of research organization has been significantly changed through center-related activities.

The degree to whcih national commentators agreed on the acceptability of such advice varies from person to person. In some cases influence is ascribed to a particular individual. Norman Borlaug is probably the most mentioned person in this regard. During the 1960s and 1970s he was personally instrumental in engendering organizational changes in many countries, especially in S. Asia. In other cases there was hardly a mention of center influence, even where it is fairly obvious to even the casual observer. Witness, for instance, the present structure and new program areas of the Bangladesh Institute for Development Studies, and the similarity to IFPRI, with which it has been actively collaborating.

In several such cases, it is more a deduction of the outside observer than a statement of involved local personnel that the models for organization of research are influenced by the international center examples. Issues of national pride sometimes curtail the degree to which such attribution is made. In India, for example, several people mentioned the enchancement of

commodity-specific activity in those commodities in the ICRISAT research mandate, subsequent to the establishment of ICRISAT. Such a claimed change in domestic resource allocation may not be quite what had been envisaged by the founders of the CGIAR, but for a country to give more appropriate attention to previously somewhat neglected commodities seems, on balance, a desirable outcome.

5.5.5 Experience with ISNAR

The most recently created international center, ISNAR, is precisely concerned with these broader issues of institutional development. This center or service, along with some other international organizations operating in the same sphere, assists national agencies concerned with research and extension to improve their organizational structures and planning procedures and, presumably, their overall effectiveness. Naturally, ISNAR also makes use of the other international centers as models.

The experience with ISNAR reflects the wider experiences with outside advice on institutional restructuring. Predictably, it is a somewhat mixed story. Most countries have welcomed their association wtih ISNAR and have actively implemented plans jointly worked out through this service. Some take quite some time to implement most of the recommendations (e.g., Papua-New Guinea) but are committed to doing so and still value highly the joint planning activities. Some countries have used the occasion of an ISNAR review as an opportunity to take a fresh and wide-ranging look at the organization of their research. This can lead to somewhat mixed feelings about the role of

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ISNAR in the process. Malawi is a case in point. After objecting to the ISNAR recommendations and conducting its own re-review, the government proceeded to implement a new plan which, for the most part, was remarkably similar to the ISNAR plan.

The broad view of the impact of ISNAR is rather positive. Research personnel in several countries where ISNAR has not yet had either an opportunity or an invitation to work, expressed their hope for future involvement of ISNAR in the development of a more effective organization for agricultural research.

5.6 Views on Policy Research and Implementation

5.6.1 Independence, self determination and a role for centers

National governments are naturally protective of many aspects of their independence. In terms of agricultural research in the large, germplasm and research techniques tend to cause few challenges to the more overt feelings of independence. However, issues of institutional change and research organization are areas where feelings about self-determination and independence tend to be strong. Many of the people interviewed expressed their concern about what they saw as the more dictatorial policy agencies, whether these were identified as international financial institutions such as the IMF or the World Bank or other outside agencies such as the centers themselves. Most people active in policy making try to consider a range of alternative sources of wisdom from which to prepare to take their decisions.

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5.6.2 Sharing experience, and the transferability of policy

Policy makers in many countries feel that there is much to be learned from the experiences of others whom they perceive as facing similar policy-making challenges. This is especially relevant in contemplating the impact of research by IFPRI. High-level decision makers in India, Kenya, Bangladesh, Egypt, Zimbabwe and the Philippines expressed to members of the study team their active interest in seeking out research findings and other information on particular policy initiatives, (e.g., food subsidy policies in Egypt) even though their own situations vary greatly from those in the research case study countries. They felt that there was much to learn from analysis of the problems faced by others and of the advantages and disadvantages of programs that had been implemented.

5.6.3 Experiences with IFPRI

IFPRI works in a challenging environment because in each country there are many national agencies concerned with policy formulation. Rather than dealing only with a Ministry of Agriculture and its research substructure. IFPRI usually deals with several departments that are significant in policy formation. For example, it typically has close working relationships with the Ministry of Finance and the Treasury as well as national food agencies - and this seems as things should be. Sometimes, however, this leads to some uneasiness among collaborators in the Ministry of Agriculture because they feel that their own role in agricultural planning may be being undermined.

Some policy makers emphasize the crucial nature of the bridge that IFPRI makes between activities of other international centers and the national programs. Part of this bridging stems from the role of other outside agencies in the policy process. For instance, the World Bank is a considerable force in policy work because it typically includes strong normative directions in the terms that are negotiated on loans. IFPRI does and, indeed, should help to bridge gaps between such outside forces and natonal programs, particularly if it maintains an independent research stance on the issues under discussion.

Several senior policy makers expressed their admiration for the high degree of professionalism maintained by IFPRI. They made the point that IFPRI needs actively to prosecute the highest standards in its research work because, should these be perceived to be compromised any way, the credibility of the center would be immediately threatened. Some people in the policy making process expressed enthusiasm for the insights provided through IFPRI analysis. To quote one Minister of Agriculture, "We not merely welcome but really want the IFPRI analyses and are positively impatient for them. I need them now. They are just right and are on the right subjects. We like the cross-country comparisons as well as the case histories. They are invaluable in Cabinet in the battle for resources between ministries, and are especially needed because other ministries such as industry can provide clear cost-benefit cases to their ministers, and this is very hard in the area of agriculture".

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In spite of the delicate issues of self determination in policy work, many people concerned with policy formulation expressed their appreciation of working with IFPRI on a policy issue. They felt that their own analysis gained credibility and greater impact in policy determination if it was accompanied by an IFPRI analysis. This added stature to their own work, which in some cases was conducted in collaboration with IFPRI.

One of the observations made in several countries was that a reason for the relatively positive attitude toward IFPRI is that IFPRI often works with young academics with advanced training and these people often rise quickly to important government jobs. An experience in joint policy analysis with IFPRI can thus be carried to the highest levels of national decision making in a brief span of time.

In the context of national sensitivities, it might seem possible to distinguish between policy analysis, exploration of policy options, and policy advice. In practice, however, several national authorities expressed their belief that they were essentially the same thing. A good policy analysis that makes issues clear was seen as tantamount to the direct offering of advice. In spite of the lack of recognition of a distinction between analysis and advice, these countries were warm in welcoming policy analysts from IFPRI. The center was seen as being a dispassionate source of independent and professional thinking on topics that are inevitably awkward.

Authorities in several countries were seemingly concerned that they were under too much pressure from donors on awkward domestic issues such as rural development policies. The need for reliable and independent analysis such was perceived to be available through IFPRI was frequently expressed. Some countries feel a need to become more sophisticated with donors so that their own national priorities can be adequately embedded in programs that are assisted from external sources. Senior administrators in several countries expressed their awareness of the sensitivity with which IFPRI must proceed in many of its analyses.

The thorny ground of regional trade issues in policy was suggested by some as a continuing priority area for IFPRI, in spite of any political difficulties it might bring in its train. Even more delicate is the potential work on land tenure issues which, perhaps rightly, IFPRI so far has not entered. Several authorities in the developing countries expressed their hope that IFPRI would, in due course, do some substantive work in the field of land tenure. From IFPRI's point of view, this is seen as a relatively straightforward issue that does not require much new research. From a country's point of view, it would value the opportunity to have an outside body to be seen as sharing some of the "hard decisions" in analysis of the contentious political issues of land reform.

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Several senior African policy makers who had attended the IFPRI-organized agricultural policy seminar at Victoria Falls expressed their appreciation for the initiative and were enthusiastic about the value of the meeting. It was a good opportunity to share problems and they felt that it was well planned, organized and run.

A recent conference sponsored by IFPRI brought together senior policy advisors from 20 developing countries with research analysts in a review of food subsidies. A number of the delegates noted the value of an opportunity to discuss common problems with colleagues from other countries and to engage in debate with the analysts. IFPRI's research output was unanimously regarded as being of high quality by those respondents who commented. However, one researcher claimed that "the work of IFPRI is too centralized in Washington and therefore its impact in generating useful policy directions in developing countries will be very limited".

These few reports of national views of IFPRI's contributions illustrate how different is its operating environment from those faced by the other centers and thus, yet again, the diversity of the CG system and of national perceptions of its centers' works.

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5.7 Coda

* The centers concerned with plant improvement have given high priority to providing national collaborators with pools of genetic materials of intersting diversity. In every country study, the provision of germplasm of important food crops was most frequently cited, along with training, as the most valuable contribution of the centers.

* Since the development of international rice nurseries, rice breeders have obtained germplasm easily and routinely. Wheat varieties were exchanged more regularly between some countries. However, countries with less developed research systems had little or no access to these sources until CIMMYT organized its international nurseries.

* Until CIAT and IITA began active provision of cassava clones there was virtually no organized source for such materials. Seed potatoes could be obtained from commercial sources but, until CIP's program, there was no systematic way that developing countries could obtain a selection of potato varieties liikely to be superior for their environments.

* The availability of the germplasm collections and networks has signficantly raised the goals of research. Cuban scientists, however, were concerned that the rice materials they received from CIAT had been too closely selected for traits that were not necessarily relevant to Cuban circumstances.

* A positive counter-example, in this respect, is Malawi's collaboration with CIAT. The center continues to respond to the country's requests for bean material in a most specific manner. Thus the country receives material specified according to request by seed colour and size, disease resistance, growth habit, etc.

* Several national programs have been closely modeled after a center. The green revolution and its accompanying publicity was credited by many research workers as having been very important in increasing the level of investment in agricultural research.

* Sometimes the existence of a collaborative arrangement with the centers serves to protect the budget of a national program in times of fiscal stringency. Research administrators in several institutions told the study reporters how they had used the presence of the centers or center activities to lever more resources from their governments.

* Centers are perceived as having been quite successful in passing on skills and techniques, e.g., mass rearing of insects, artificial innoculation of crops, gathering and storing rust innoculum for evaluating disease resistance, population breeding, vacum emasculation, etc. Many countries have now instigated farming systems research programs, partly at the behest of donors and with the assistance of the centers, and partly because research planners have been impressed by the idea.

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* The individuals who reported having training in the centers were generally positive about their experiences. Researchers in Kenya indicated that the vairous courses offered by the centers were particularly beneficial for the technical cadres and first degree holders. Courses in modern production methods served a useful purpose, especially in newly created programs with little or no local history of research.

* Training courses conducted in their home countries were rated as particularly useful by researchers in Ecuador, Malawi, Zimbabwe and Cuba, for example. The Cubans expected to rely heavily on the centers which offer traiing in tropical agronomy not otherwise available to them. Training by ICARDA is reported to have led to the establishment of two new departments within the field crops section of the Syrian national program.

* The center's systems of selective dissemination of information from the world literature to colleagues in partner countries provides material selected on the basis of declared interests of the recipients and is appreciated by them.

* Some scientists felt that the nature of the services of the centers was not widely enough known and understood, and that more promotion and information is needed. However, many, including some from Mexico, Malawi and Zimbabwe, were concerned that the publications they received were often too general to be of use in their scientific endeavors. Technical

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reports were seen as being more useful in the hands of research workers yet many, especially those away from the main center, have very poor access to such material.

* Many respondents challenged the centers to "provide" greater numbers of post-graduate scholarships, institute research and post-doctoral opportunities. An expansion of resources to support center-based thesis research opportunities for students taking degrees at industrial country universities is one alternative that was suggested by several authorities in the developing countries.

* National agencies and authorities can be more or less receptive to advice on how their institutions may best be organized or reorganized. The experience with ISNAR reflects the wider experiences with outside advice on institutional restructuring. Predictably, it is a somewhat mixed story. Most countries have welcomed their association with ISNAR.

* In spite of the delicate issues of self determination in policy work, many people concerned with policy formulation expressed their appreciation of working with IFPRI on a policy issue and also of seeing the results of carefully worked policy research.

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PN-AAZ-939

INTERNATIONAL AGRICULTURAL RESEARCH CENTERS:

ACHIEVEMENTS AND POTENTIAL

Part III

A Study
Directed by Jock R. Anderson

Draft of August 31, 1985

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Part III REALIZED CONTRIBUTIONS OF THE PARTNERSHIP

Overview

Contributions that can be measured in concrete terms are clearly at the heart of any study of the impact of technological innovations arising from research. Reflecting the importance of plant breeding in CGIAR institutions, the first contributions addressed in this Part are those associated with germplasm. While the centers have been demonstrably important in the development of modern varieties, they are by no means the only actors in the scene. There are many research institutions in both the industrial and the developing countries that have been involved in the development of improved varieties and other related innovations. Indeed, the centers work closely with national agricultural research systems to improve their mandate crops.

Aspects of the story of modern varieties, especially of rice and wheat, have been told often and from many perspectives. The first chapter of this Part, however, deals more broadly with all the significant plant improvement programs at centers. So far as possible the spread of modern varieties is documented (chapter 6) and associated with the consequential changes in productivity and output. In the later chapters (beginning in chapter 7) the consequences of technological innovations other than modern varieties are addressed.

The complex issues of the distribution of benefits of technological innovations are addressed in chapter 8. These distributional questions cover the earnings of labor, land and capital and the geographic, social, economic and nutritional dimensions of the distribution that have attracted the

attention of critics of agricultural innovations. Much attention has been addressed to the production side of agriculture. There is a need for more concern for the consumer beneficiaries of changing agricultural productivity. Increasing numbers of consumers in the lower income areas of the world are clustered in large urban aggregates, so the provision of food to these dense populations which have no direct access to agricultural production demands serious attention.

Some of the other important but diverse products of the centers are also reviewed in chapters 9, 10, and 11 even though some involve dimensions that are difficult to quantify. The first is in the broad area of enhancement of human capital. The centers are all engaged in training programs of some sort although not all identify their activities that raise human capital as training *per se*. However they may be identified, the number of people who have received some assistance in their professional development now runs to more than 17,000; over 90 percent are men. They are nearly all working in partner countries, most of them in the research centers from whence they departed for their training. This topic has been the subject of an intensive investigation by consultants to the TAC in a study parallel to the present one, and their main findings are drawn together in chapter 9.

The final two "products" reviewed in this Part concern institutional changes discussed in chapter 10 and, in chapter 11, policy matters. Among institutional arrangements, the key issue to consider is the capacity of national programs to engage in agricultural research and to deliver the results to the target population. There are almost as many variations of institutional structure and organization as there are countries, and there is much to learn from comparative analysis of their experiences. Indeed, ISNAR

is addressed to such learning, and to extension of things that are found to work.

The final topic considered in this Part concerns research on policy for the agricultural and food sectors. Of course, IFPRI has this as its mandate, but all the other centers are concerned to some extent with policy matters, despite their restricted commodity foci and their heavy emphases on long-term biological research.

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6 PLANT MATERIALS

6.1 Introduction

The variety-related accomplishments of the collaborative research between the CGIAR centers and agricultural researchers in developing countries are addressed in this chapter. The extent of varieties released, their spread, their breeding, their effect on food production and its stability, and their contribution to increased agricultural productivity are examined. Matters relating to germplasm *per se* are taken up in chapter 12.

6.2 Collaborative Research in Varietal Development

Several joint products can be identified as resulting from the collaborative work of the international centers and the national programs on varietal development: (a) varieties obtained from one country and supplied as promising materials by an international center to researchers in another country, (b) varieties developed and made available by centers, (c) varieties selected by national programs from crosses made by and selected as promising materials by an international center, (d) varieties selected by national programs from crosses made at an international center and supplied to a country as early generation segregating material, (e) varieties resulting from crosses made by national scientists from parent material supplied (perhaps in part) by an international center, with selections made by national scientists, and (f) varieties resulting from more complex cooperation such as crosses made by either international centers or national researchers with evaluation and selection made by both in alternating generations from materials shipped back and forth between a center and a national program. While all these and

possibly some other kinds of genetic material may be related to centers, varieties developed independently by national programs from crosses with one or more center parents are not center-related in the sense used here.

It is the intention in this study, to use "center-related" or "center-derived" to designate varieties developed by processes (a) through (d), but full information about all varieties is not always available. Furthermore, because of the many possible ways in which germplasm from a center and a national program may be combined, evaluated and selected, it is impossible to quantify the contributions of national programs as distinct from centers. For example, the Brazilian rice variety CNA 7 was introduced from India as IET 2881 where it had been produced from a cross of T 141 with IR 665-1-175-3. A Brazilian maize synthetic, BR 105, was developed in the early 1980s by EMBRAPA from germplasm originating in the Caribbean and selected in Thailand by CIMMYT. Increasingly, national programs are taking over more of the collaborative process of plant improvement. Every effort has been made in what follows to designate as "center-related" varieties only those in which centers' had a direct hand, i.e., those described in (a) through (d).

6.2.1 Naming varieties

According to a dictionary definition, a <u>crop variety</u> is a recognized, genetically homogeneous group of plants of less than species rank. Farmers and plant breeders (sometimes one and the same) use "variety" to refer to a group of plants that are recognized as having a set of inherited characteristics differentiating them from other sets of the same crop and which have been given a name and are approved for cultivation, either by custom or by some duly constituted authority.

A land race is a set of plants of a crop of a less homogeneous nature than a variety, but still similar, which has been recognized by custom or tradition. Land races are sometimes highly heterogeneous and are normally found in agricultural systems isolated from interchange with other systems. Farmers and lay persons sometimes call these varieties, while plant breeders and geneticists usually prefer the term land race or "primitive form".

Lines are small sets of plants in the intermediate stages of varietal development. Because of the nature of plant breeding, lines are less homogenous than varieties, and therefore provide scope for selecting individual plants with performance superior to that of other individuals in the same line.

Cultivar is used as a more specific term than variety or land race, to identify a homogeneous set of plants cultivated as a crop. The word also has a more technical meaning related to official description and registration in some countries.

A hybrid is the result of a cross between two different cultivars. In common use, hybrid denotes a special type of variety produced through crossing inbred lines; seeds of a hybrid must be produced each year by making the same crosses. Conventional varieties are produced by creating a hybrid and then selecting from successive generations until uniform offspring are produced. Varieties of cross-pollinating or out-breeding crops such as maize may consist of various kinds of population mixtures or composites of genotypes.

While varieties may acquire recognition through informal processes, in today's world, for all practical purposes, they must be named. The act of

naming indicates approval by the naming authority that the variety is suitable for cultivation under certain conditions. Depending on the availability of information and resources, and the extent of control by the authority, the specification of the conditions for which a variety is suitable may be rather general or quite specific.

Most countries grant the authority to name varieties to national variety registration boards (sometimes "seed boards") but, in some large countries, state or provincial seed boards may have the authority to name varieties. Seed boards usually require the individual or institution proposing cultivars for naming to provide evidence of performance and some minimal quantity of "breeder's seed" to permit evaluation of performance and to provide the basis for subsequent multiplication.

Most CGIAR centers do not name varieties although, for example, until 1975 IRRI did name varieties that were used within the Philippines and elsewhere. Seed boards in many countries use the designations of plant breeders as names for varieties where they are suitable, or choose some name that indicates the institution or organization responsible for developing the variety. For example, CSH-1 designates coordinated sorghum hybrid 1, the first hybrid sorghum developed by the All-India Coordinated Sorghum Improvement Programme. Similarly, many countries use an abbreviation of the center designation when they name center-related varieties while others choose unrelated names.

6.2.2 Time requirements for varietal development

Plant breeding is a time-consuming process (Figure 6.1). It starts with collection of existing varieties, breeders lines, mutant stocks and land

Figure 6.1

STAGES IN THE DEVELOPMENT OF CROP VARIETIES

Collection and characterization of germplasm
(1 to 4 years)

↓

Selection of land race germplasm or other breeding material
(1 to 3 years)

↓

Generation of segregating lines through crossing
(1 season)

↓

Screening segregating lines against stresses
(5 to 7 seasons)

↓

Selection of elite lines
(2 to 4 seasons)

↓

Preliminary and advanced yield testing
(2 to 4 seasons)

↓

Distribution in international trials
(1 to 3 seasons)

Period required for development: 6 to 14 years

races; these are studied and examined for useful characteristics. Then pairs of cultivars are crossed to produce F_1 hybrids (the first generation). The F_1s are planted and harvested to give F_2 seed, which in turn is planted to give the F_3 generation, and so forth. Sometimes the F_1 is backcrossed to one of the parents or to another cultivar. Each time a new generation is grown, the plant breeder has an opportunity to observe the reaction of the crop to whatever set of circumstances exists or is created. If a particular generation is grown during a droughty season that kills most individual plants but through which some survive, the individual surviving plants have a greater degree of resistance to or tolerance of drought. These early generations "segregate" in their reaction to particular stresses because each individual plant has a different combination of genes. Subjecting the plants to the same stress for a number of generations ensures that only those resistant to that stress will survive.

Plants are purposively subjected to a series of stresses, i.e., "screened" against insects, plant diseases, acid or alkaline soil conditions, or other factors, in order to observe their reactions. Depending on the genetic dominance or recessiveness of a characteristic, resistant plants may be identified by screening over a number of generations (dominant), or in a single generation (recessive).

The process is time consuming because one season is required to grow each complete generation, and because screening for different characters is normally carried out sequentially, although seed lots can be divided and subjected to different stresses at the same time. In addition, most important plant characters are controlled by many genes. Thus, drought resistance is a complex characteristic to which many plant mechanisms such as leaf stoma

reactions, leaf wax composition, root density and root length, all contribute. After identifying several lines that each carry a gene for one desired characteristic, additional crossing and selection is required to combine the several desired genes into a variety that has the necessary characteristics.

The breeding process can be speeded up somewhat by growing alternate generations of a normally rainfed crop with irrigation in the "off" season, in a greenhouse, or by rotating through different climatic areas. This also subjects the generations to different sets of growing conditions, which naturally affects the combination of genes in the resulting selections.

After five to seven generations of screening, the best remaining lines are selected as elite lines and subjected to preliminary yield testing, which requires a greater quantity of seed than for selection in the early generations. If a line is good enough it goes on to advanced yield testing, and then perhaps to an international or multilocational national yield trial. Advanced lines may be entered in "observational trials" in a number of locations so that plant breeders outside the originating station may observe performance under local conditions. By the time a variety is named, it has been evaluated for many characters by a number of plant breeders and others.

Additional time is required for national authorities to test and evaluate the suitability of received materials for their individual conditions (Figure 6.2). Normally they evaluate materials in a preliminary way (often as part of an international nursery). Promising materials go on to advanced trials and then to farmers' fields. The process may be cut short somewhat by evaluating earlier in farmers' fields, but only a relatively few lines can be evaluated in farmers' fields because farmers are naturally more interested in

Figure 6.2

STEPS IN TESTING VARIETIES BY NATIONAL PROGRAMS PRIOR TO RELEASE

Preliminary national trials
(2 to 4 seasons)

↓

Advanced national trials
(2 to 4 seasons)

↓

Farmers' field tests
(2 to 4 seasons)

↓

Consideration by varietal release authority

Period required for testing and release: 3 to 6 years

growing crops and running their own informal trials of materials and practices than acting as de facto directors of experiment stations. Testing under farmers' conditions is more expensive for national authorities than on experiment stations because it involves additional travel and supervision costs. Three to six years usually elapse between first evaluation and release of a new variety.

A minimum of six years may be required between initiation of germplasm collection and identification of promising lines from it. Where highly seasonal rainfall or temperature regimes restrict evaluation to only one cycle each year the process may take up to 14 or even more years. Three to six years may be needed for evaluation in a country that carefully examines materials obtained from outside sources. Even where cultivars are simply collected and supplied to national researchers for evaluation and local testing, several years elapse between the beginning of a program and the naming of varieties by countries. The research that led to the release of CIMMYT wheats in the mid-1960s began 20 years earlier in Mexico and elsewhere. IRRI was fortunate that its cross of a semi-dwarf rice from Taiwan with a high quality tropical variety from Indonesia produced IR8 within five years, but such good luck is unusual. Researchers in Thailand started working with Rockefeller Foundation scientists to develop improved maize in 1959. The first variety was released in 1969 but it was not resistant to downy mildew. Not until 1975 was the first resistant variety released. Where a crop is not receiving much research attention, even direct transfers take time. Chile began research on chickpeas with materials imported from the U.S.A. in 1976; the first variety was launched in 1983.

Centers that began breeding programs in the late 1960s and early 1970s on field beans, cassava, cowpeas, chickpeas, tropical sorghum, pearl millet and tropical pastures had to begin by collecting germplasm and determining how the existing varieties could be improved. The base of knowledge and collected germplasm on which to build was small in these crops, so it is not surprising that the early products are just being named by countries in the early 1980s. Ten years after IRRI began, countries other than the Philippines had named 10 lines developed at IRRI as varieties. Fifteen years after CIAT began its bean program, 20 varieties had been named by country programs. Fifteen years after IITA began its cowpea research, 21 of its varieties had been named by country programs. Thus, it is clear that, by 1985, the CGIAR centers, including those that started later than CIMMYT and IRRI, are indeed seeing the fruits of their varietal development work accepted by developing countries and their farmers. Rates of farmer adoption are influenced by several biological attributes, including the different rates of potential multiplication associated with the various methods of propagation used for different crops.

Since the late 1970s, an ever growing number of lines of crops have been developed by the centers, distributed through international varietal testing programs for evaluation by national authorities, and named by national seed boards. An increasing number of national programs are obtaining segregating lines from centers and doing their own screening, selection and yield testing. Because the seed boards are independent and are located in countries throughout the world, it is impossible to have information about all the varieties named, but a summary of information about those known to have been named as of mid-1984 is presented in Table 6.1. Because the table shows numbers of varieties released by countries, and not number of germplasm lines, it reflects multiple counting of lines released by more than one country.

Table 6.1 Number of CGIAR center related varieties released by national authorities in developing countries through 1983[a]

Crop	Number of varieties named by countries in				
	Africa	Asia	Latin America	Middle East & North Africa	Total
Barley	0	2	0	8	10
Beans, field	4	2	90	0	96
Cassava	26	5	32	0	63
Chickpeas	0	1	0	2	3
Cowpeas	14	2	12	1	29
Maize	61	49	126	2	238
Pasture species	0	0	12	0	12
Pearl millet	5	3	0	0	8
Pigeonpea	5	2	0	0	7
Potatoes	31	16	12	2	61
Rice	31	140	129	2	302
Sorghum	8	18	5	0	31
Sweet potatoes	6	0	0	0	6
Triticale	2	2	7	0	11
Wheat, bread	40	44	114	66	264
Wheat, durum	5	3	13	20	41

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[a] Excludes varieties developed from crosses made by national programs from sources similar to those used by the centers.

It is evident from the table that research on the various mandate crops has reached different stages. Countries have evaluated and released large numbers of wheat and rice varieties. Their spread is discussed in section 6.3. A smaller number of maize, cassava, field bean, potato and cowpea varieties have been named, along with a few of chickpea, pearl millet, sorghum and some pasture species.

This is not to suggest a larger role for the centers than they have played. Many national research systems have developed and released improved varieties independently of the centers, in addition to those developed in cooperation with the centers. For example, there are 52 varieties in a list of improved rice varieties named by Indonesia; of these 18 are directly center-related and are counted in the listing of Table 6.1. A similar effort has been made to exclude varieties of other crops only distantly related to the centers.

6.2.3 Center-related maize varieties

Based on materials supplied from the centers, over 200 maize varieties have been developed and released by national authorities in 41 countries. Most of these were named by Latin American countries, but countries in Asia and Africa have named about 50 in each region. One particular group of lines called "Tuxpeno" has been of special value in obtaining disease resistance for lowland tropical areas; the discovery and incorporation of streak resistance into advanced maize lines by IITA has been important for maize production in African countries. It is estimated that the center-related varieties are being grown on over 6 million ha in developing countries, including Costa

Rica, Brazil, Ecuador,Mexico, Guatemala, Honduras, Ghana, Tanzania, Nigeria, China, India, Burma and Thailand.

Even though these releases have been made, the maize research of the centers has had less impact on production of foodgrain than has wheat or rice research, raising the question of why. At least four factors contribute. First, maize is grown under a great diversity of conditions in the developing world, and any individual variety is adapted to only a narrow range. Thus a great many individually adapted varieties must be developed, and these can only effectively be adapted by local researchers. This contrasts with irrigated wheat and lowland rice which are grown in fairly homogenous environments. Second, in the developing world, maize is grown in many countries, unlike rice which is concentrated in Asia, and wheat which is concentrated in the Indo-Gangetic plain, the Middle East and North Africa. Thus international maize researchers must forge a greater number of institutional links than must wheat or rice workers in order to reach the same proportion of national maize workers. Third, while it might appear that a large backlog of plant improvement existed for maize before the centers started, in fact, the prior research was addressed largely to yellow dent types, while people in developing countries who eat maize mainly use white flint types. Fourth, because the improved maize populations from CIMMYT and IITA have no universal physical characteristic such as semi-dwarf stature, their crosses with local varieties and their adoption by farmers is much less apparent than was true for semi-dwarf wheat and rice.

Despite these problems, there has been considerable use of center-related maizes both directly and in national breeding programs. Reflecting the widespread nature of maize production, national researchers in most of the

country case studies commented on the contribution of center-related maize germplasm.

Researchers in Brazil reported on 12 released maize varieties that had been selected from crosses made with germplasm from CIMMYT or from CIMMYT populations since the late 1970s (Homen de Melo 1985). About half of these contained Tuxpeno genes, and most were cited for their resistance to downy mildew, Helminthosporium or other diseases, as well as resistance to lodging. One was cited as drought resistant. Each was recommended for certain states or portions of states. Brazilian maize breeders have developed many more varieties unrelated or more remotely related to center-supplied germplasm.

Researchers in Guatemala have produced nine varieties and three hybrids from CIMMYT-supplied germplasm (Stewart 1985). Nine of these have been released since 1978. A high quality protein variety, Nutricta, has been released and is being grown on about 500 ha. National plant breeders have also selected varieties for the highlands where no imported materials seemed to work.

National scientists of Costa Rica estimate that 10 to 15 percent of the 1984 maize area was planted to TICO V-1 Mejardo and Diamantes 8034, two varieties developed by the Ministry of Agriculture from materials supplied by CIMMYT (Stewart 1985).

In the Sierra region of Ecuador, the activities of the Andean maize Improvement Agreement involving CIMMYT and several countries of the region have resulted in the identification, testing, release and adoption of varieties for farmers. Because they are developed locally, they are highly

adapted, and varieties have already been launched that have been adopted by farmers (Posada 1985).

Zimbabwe has an advanced maize breeding program of its own, which started in 1930 and, in 1949, released the first commercial hybrid maize produced outside the United States (Billing 1985a). A significant achievement of that program was the release of the widely grown 150-day hybrid SR52, based on two local parents. Subsequently, 130-day hybrids have been released. Some material from CIMMYT's high lysine program is being incorporated but the high lysine gene is associated with a soft kernel. Zimbabwe's researchers are backcrossing elite inbred lines with streak-virus resistant sources from IITA. Kenya, like Zimbabwe, grows hybrids extensively and is using center germplasm in the development of new parent lines.

Nigeria has made good use of two maize populations, TZB and TZPB, which were developed during the early days of the IITA program. TZB originated from African and Latin American sources with major contribution from Nigerian Composite B. TZPB is derived from Tuxpeno Planta Boja Cycle 7 from CIMMYT. The two populations were released from Nigeria's National Cereals Research Institute under the names FARZ 27 and FARZ 34. Both have good resistance to tropical rust and lowland blight. They are the most widely grown varieties in Nigeria with a total of 200,000 ha reportedly under these varieties in 1981, according to the National Accelerated Food Production Programme. It is estimated that the two varieties were grown on about 1 million ha in Nigeria in 1984 (Okoro and Onuoha 1985).

CIMMYT has been supplying Malawi with germplasm for 15 years (Billing 1984b). Its major thrust in the 1960s was on composite varieties. The first,

Chitadze Composite A (CCA) contained 80 percent local materials and 20 percent material imported from other African countries. The second, CCB contained about 60 percent CIMMYT materials but it was not sufficiently resistant to diseases. Currently breeders are working on a third, CCC, which has a higher percentage of CIMMYT material and gives about 10 percent higher yields under drier conditions. Another newly released variety, selected from Tuxpeno, has been under local development for 10 years and is somewhat more resistant to drought than CCC.

Tanzanian plant breeders have used germplasm from CIMMYT and IITA maize populations such as La Posta, Pool 16, TZSR-W and TZSR-Y to obtain streak virus resistant cultivars that have recently been released or are being released (Ndunguru 1984).

Researchers in Cameroon have tested over 100 composites of center maize and have released a number (Lyonga and Negwo 1985). TZB and TZPB, as in Nigeria, have proved to be attractive to farmers. These two varieties cover some 10-15,000 ha in the country. Several other varieties have also been recently released.

Thailand has been the center of an inter-Asian maize improvement program since 1959 when the Rockefeller Foundation stationed a field staff member there (Isarungkura 1985). Plant materials were imported from Guatemala, crossed and evaluated in Thailand and other S.E. Asian countries. In 1969, the first improved variety for Thailand was released from the program. The program cooperated closely with CIMMYT and countries of the region to develop downy mildew resistant (DMR) materials, and in 1975, DMR Suwan No. 1 was released. Subsequently, other DMR materials were released and, by 1984,

national authorities reported that virtually all the maize grown in Thailand (about 1.7 million ha) was derived from this program.

Indonesian farmers also derived some benefit from new CIMMYT-related maize varieties which, together with improved cultural practices, have helped to raise average yields from 1.1 t/ha in 1973 to 1.7 t/ha in 1983 (Nestel 1985). In the Philippines, the DMR varieties have been less successful and, in recent years, private companies have begun to develop high-yielding hybrids that are finding acceptance among some farmers producing maize for the feed market.

Maize is a minor crop in Burma, but it is suited for human food as well as animal feed. In 1978, the government undertook a maize production program with the assistance of UNDP/FAO. The project obtained germplasm from countries in S.E.Asia and from CIMMYT to test for local adaptability, drought tolerance and early maturity (Zin 1985). Six varieties have been released from the program and have been well adopted by farmers.

6.2.4 Cassava, beans, potatoes, millet, sorghum and cowpeas

Cassava. Twenty-six varieties of cassava related to IITA germplasm have been named and released by six African countries and over thirty varieties related to CIAT germplasm by ten Latin American and Asian countries. The spread of improved cassava has been slowed by the slow growth of demand for cassava in Latin America, but the demand is expanding more rapidly in most African countries.

IITA researchers have incorporated resistance to a number of cassava pests, including the green spider mite, cassava mosaic virus and cassava mealy

bug. All of the country case studies in Africa report these are actively being tested. Researchers in Nigeria and Cameroon collaborate with IITA by supplying materials for evaluation and conducting preliminary, advanced and uniform yield trials (Okoro and Onuoha 1985). A number of clones have been identified as superior to local ones in uniform yield trials. Kenya has just begun to test IITA materials (Ruigu 1985). Tanzania is testing IITA materials for tolerance to major pests (Ndunguru 1985).

Zimbabwe's research department had not devoted much emphasis to cassava in the past, since it was a minor food crop (Billing 1985a). Migrants from Malawi have increased the demand for cassava and the department has recently started agronomic trials on materials supplied to them by IITA. The University Crop Science Department has also started a cassava research program. The range of available materials has been adequate to enable the national system to forgo a breeding program.

Cassava is more important in Malawi. IITA has made a major effort to assist the country in establishing a research program (Billing 1985a). National researchers were trained and encouraged to evaluate local material before attempting incorporation of IITA material; the center assisted in devising a strategy to assist national research and extension workers to gain farmer adoption of the new varieties.

Field beans. Over 90 CIAT-related field bean varieties had been named by 18 Latin American countries by mid-1984 and five countries outside the region named CIAT-related beans. Many of these are Dorado beans, a group of new varieties that are resistant to the bean golden mosaic virus. In Guatemala, surveys by the Instituto Interamerican do Cooperacion para la Agricultura

(IICA) in 1982/83 indicated that 40 percent of the smaller-scale bean growers and 60 percent of the larger-scale growers had switched to the Dorado varieties (Viana and Pachico). In Costa Rica, it is estimated that 35 to 40 percent of bean area is planted to varieties developed in collaboration with CIAT (Ballestro 1985). In Cuba, since 1981, about half the bean area has been planted to ICA-Pijao, a variety introduced through CIAT. Over 10,000 ha are planted to the variety in the state farm sector while private sector plantings have averaged 5000 ha. A survey of farmers in the four Argentinian states that account for 95 percent of the black bean production of that country indicates that, in 1984, improved varieties were being grown on 65 percent of the area (Gargiulo 1985). In addition, Mexico, Cuba, Argentina, Haiti and the Dominican Republic are multiplying the Dorado bean seeds or had them growing on farmers' fields in 1984.

Farmers in Guatemala reported an average yield of 910 kg/ha with the new beans compared to 750 kg/ha with their traditional varieties. There was no difference in the use of other inputs between the two types. In the Costa Rican case study, farmers reported yields of 1050 kg/ha for the new variety Talamonca compared to 940 kg/ha for an earlier introduced variety, and 600-700 kg/ha for traditional local varieties. In Argentina, yields of the new beans averaged 1360 kg/ha, a 26 percent increase over local bean varieties. Apart from adopting the new variety, farmers do not appear to have changed their production practices, so the entire increase in output except for the cost of new seed is a net gain.

Even where CIAT varieties are not directly suitable for conditions of the country they can make a contribution to varietal advance. For example, in Chile, research on beans has benefited from the support of CIAT which has

supplied lines resistant to mosaic and root fungi since 1975. CIAT has also made specific crosses for the Chilean national program.

In Brazil, the contribution of CIAT bean varietal improvement work is just at the stage where it will begin to make an impact. Researchers identified seven varieties being released to farmers in 1983 or 1984 that they had developed by selecting or crossing center-derived materials, or varieties developed in other countries from center materials.

Potatoes. By 1984, 23 developing countries had released or named 61 potato varieties developed from germplasm provided by CIP. CIP obtained many of these from ongoing potato research programs in the industrial world through their contract research program. Other varieties were collected by CIP researchers from national programs in one location and provided to researchers elsewhere in the process of germplasm exchange. At the same time, improved potato lines developed by CIP breeders that combine resistance to the most important diseases are being evaluated by national researchers in 53 developing countries. Varieties resulting from these breeding efforts are expected to begin to be named in the next five years.

The strategy being followed by CIP to introduce improved germplasm is illustrated by the case of the central African highlands area where about one million small-scale farmers in Rwanda, Burundi, Zaire and Uganda grow about 120,000 ha of potatoes annually. The first step in the strategy was to select improved local varieties from farmers' fields for cleaning up and multiplication in seed units set up by the program. The second step was to introduce some improved varieties from other ecologies. The third step was to select

Feature: Dorado Bean Varieties: A Collaboration

Bean research specialists in Panama, Cuba, Haiti, Mexico, Guatemala, Honduras, El Salvador, Costa Rica and the Dominican Republic joined with CIAT during the late 1970s in a network to improve field bean production in Central America where beans supply over 15 percent of most people's protein. Each participating country within the network agreed to undertake specific responsibilities for an overall bean technology development program, with CIAT providing backup support to the joint enterprise.

Bean golden mosaic virus (BGMV) is one of the main constraints to Central American bean production, especially in the drier, lowland areas of Mexico, Central America and the Caribbean. Guatemala accepted responsibility for working toward virus-tolerant bean varieties within the network. CIAT helped with germplasm and some strategic research which included isolation of the BGMV at CIAT. After screening the germplasm bank under heavy natural pressure for promising material, CIAT researchers raised the pressure even further by surrounding the test lines with other crops that carried the virus and its vector. Crosses were made in 1975/76 at CIAT and the segregating lines were sent to Guatemala for selection under field conditions.

The selections looked excellent. One line, DOR 41, grown without chemical insecticide to protect it from the insect that transmits BGMV, yielded 1340 kg/ha while the susceptible commercial variety yielded 550 kg/ha. Basing their decision on such encouraging results, Guatemala research authorities decided to speed their testing, and released three promising lines

in 1979. The varieties quickly spread to farmers fields so that by 1982/83 they covered more than 40 percent of Guatemala's bean area.

Promising lines were sent to the other members of the network. Line DOR 60, which had been screened at the F_2, F_3 and F_4 generation level in Guatemala was taken to Mexico where it was tested by researchers in the national program and in one trial yielded 1270 kg/ha compared to 560 kg/ha for the traditional variety. It was released by Mexico in 1981 under the name Negro Huasteco 81.

Cuba selected several lines from the international nursery. The first to be released has spread to over 10,000 ha. Line DOR 15 was released under the name Tomeguin 1. Still another, DOR 41, is in the advanced testing program where it is being evaluated and adapted to local conditions. The Cuban researchers will pass the results back to the Guatemalan researchers who developed it.

The same line, DOR 41, caught the attention of Argentinian researchers through its performance in the international nursery. They saw it as a possible solution to a different disease, bean chloritic mosaic virus. They multiplied the seed and, by 1984, farmers were planting some 20,000 ha to it. Researchers in Haiti and the Dominican Republic have also selected DOR lines for their conditions and in 1984 were testing them on farmers' fields prior to seed multiplication and release.

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varieties under local conditions from among tuber families supplied from CIP. Through this strategy, large amounts of improved materials are available to farmers. Since 1979, six new local varieties that were tested at several sites and on farms have been released. Rwanda will plant around 9000 out of 45,000 ha to these improved varieties in 1984, providing the seed requirement of 2 t/ha of seed potatoes from its own production. A further step has been to test consumer preferences in relation to the different characteristics required by different coding techniques and end uses and the comparative acceptability of varieties at various price levels. Recent consumer studies have drawn attention to variability in flavor and nutritional quality of the same varieties grown in different production zones.

Pearl millet. Pearl millet is an important food crop in relatively few countries. They tend to be those that have some of the harshest environments in the crop-growing world. It is usually grown by people who have few other sources of income. India, Pakistan, Zambia and Sudan have released six pearl millet varieties derived from ICRISAT materials. Another 15 are either in the advanced testing or pre-release stages. It is estimated that, in 1984, such pearl millet varieties released in India covered nearly 600,000 ha. Varietal development work is actively in progress in Niger, Burkina Faso, Nigeria and other areas in the semi-arid tropics.

Sorghum. Sorghum is another crop grown under harsh environmental conditions by many poor people. In 1980, Ethiopia released its first ICRISAT-derived sorghum variety and since then has released three others. Burma released ICRISAT-related varieties in 1981 and 1982, and by 1984 the national authorities estimated that 23,000 ha out of a total of 190,000 ha were planted to these new varieties. Burkina Faso also released several center-related

varieties in recent years. By 1984 it was estimated that 31 sorghum varieties derived from the ICRISAT program had been released. Kenya was yield testing 40 lines and was multiplying 4 varieties prior to their release. Many lines were being used in crossing programs in Mexico, Kenya, Malawi, Guatemala and other countries.

The national research program of Sudan and ICRISAT developed a promising hybrid sorghum in January 1983 in a UNDP-supported project. Twenty tons of seed of the new hybrid, Hageen Durra-I, were planted by farmers in 1984. Under farmers' rainfed conditions it gave an average yield of 810 kg/ha compared to the 270 kg/ha given by local varieties. During 1984 about 350 tons of seed were produced, enough to plant 125,000 ha, and 2000-4000 tons of seed are estimated to be needed for 1985. If available, that could cover 0.5 to 1.0 million ha.

Cowpeas. Fourteen countries had released 29 varieties of IITA-related cowpeas by 1984. Of these, 14 had been released in African countries. Thirteen varieties are known to have been released in 1981 and 1982. The first release was by Venezuela in 1979, followed by releases in Tanzania, Burkina Faso and Nicaragua in 1980.

Nigeria released two cowpea varieties derived from IITA materials in 1983: "Dan Knarda" and "Exorowo" from TVX 3236 and IT82E-60, respectively, which have found ready acceptance by many farmers. In just one development effort, these cowpeas were being produced as a sole crop by about 9000 farmers in the Kano Agricultural Development Project in 1984. They grew a total of about 4000 ha and made profits of about 2000 Nira per hectare. Another 2000 ha are being grown outside the project area (Okoro and Onuoha 1985).

Zimbabwe has evaluated a wide range of IITA cowpeas and selected promising varieties in experiment station tests during the 1981/82 season. They were subsequently field tested and grown at sites in communal farming areas under farmers' conditions, achieving yields of one t/ha under rainfall as low as 200 mm and appeared to be extremely promising to local researchers. Seeds are being multiplied. Researchers in Cameroon likewise report that several cowpea lines are being multiplied prior to their release to farmers.

More lines and varieties of these crops are known to be in the advanced stage of testing in many countries, but as in the case of breeding, the process of testing is time consuming and one that requires a certain amount of local competence and resources. Countries require up to eight years of testing at a number of locations before varieties can be released, although in some cases, where a country has faced urgent needs and varieties appeared to be unusually well suited, seeds directly imported from elsewhere have been released to farmers.

The process of screening requires competent investigators and the process of testing requires a national varietal testing organization or at least a well qualified extension system. Countries that do not have adequate personnel or adequate budgets for such activities cannot effectively carry them out. They can, of course, grow varieties developed in other countries or at the international centers but, because the particular combination of conditions and stresses that make a variety perform well in one location may be different from what is required in another location, relying on varieties developed elsewhere may not give well-adapted varieties. This need for local screening and testing prior to release of a variety is one of the advantages

that the countries hosting the international centers have — multilocation testing of promising lines is done by the center as a part of its breeding program and so need not necessarily to be done by a national organization.

6.3 The Spread of New Wheat and Rice Varieties

To date, the bulk of the increased food production resulting from the joint research efforts of international and national researchers has been from wheat and rice. Nearly 50 percent of the wheat land and over 55 percent of the rice land in the developing countries was planted to semi-dwarf varieties in 1984. Most of these varieties are related to center-provided germplasm except for the rice in China, where semi-dwarf varieties were discovered independently. More recently China has been using IRRI varieties widely as parents for its hybrid rices. Sufficient data are available for wheat and rice to make a rough estimate of the global spread and output contribution of new technologies.

Dalrymple (1978) documented the spread of "high yielding varieties" of wheat and rice in the developing world since they were first released. He has updated that work as part of this study, and his update forms the basis for the following discussion. The precise numbers reported here differ from his, however, because he uses U.S. Department of Agriculture statistics as the basis for his estimates of total wheat and rice area while FAO statistics are used in this study.

Despite Dalrymple's efforts, complete time series are not available to show the spread of semi-dwarf wheat and rice varieties in all countries. For many countries the data show only a few scattered years. However, it is clear

that the semi-dwarf varieties continue to be grown and, indeed, continue to spread. In order to derive a consistent estimate of the total area planted to semi-dwarfs, an interpolation procedure is used based on the assumption that adoption took place smoothly over time (according to a fitted logistic function) for any periods for which data are missing beginning with the year in which the varieties are known to have been first grown and reaching the maximum reported level which is taken as the maximal asymptote etc. It is presumed that areas planted during the years for which data are not available followed the path of adoption observed in the sparse data. The parameters of the logistic function were estimated from the updated Dalrymple data but, since he does not use such a procedure, it is another source of difference between his estimates and those reported here.

6.3.1 Wheat

The wheat varieties developed by CIMMYT and its predecessor organization were shorter than the traditional wheat varieties; therein lay part of their ability to give high yields when provided with appropriate quantities of inputs. They were developed also to be resistant to the most important fungal diseases of wheat and were not sensitive to length of day in flowering ("non-photoperiod sensitive") and so were adaptable to a broad spectrum of growing conditions. Similarly, the rice varieties developed by IRRI, which became the basis for the ensuing joint work with national researchers, were shorter than traditional tropical rice varieties, giving them the genetic capability for high yields and resistance to lodging when grown with high fertilizer rates and good water control. Hence, both the improved wheats and improved rices are known as "semi-dwarf" modern varieties.

Over 260 varieties of semi-dwarf wheat had been named by 29 developing countries by 1984. Table 6.2 and Figure 6.3 summarize the data on their spread in the developing world since they were first introduced in 1965. By 1983 the international center-related wheat varieties had spread to over 48 million ha of land in the developing countries. This amounts to about 50 percent of the total area planted to wheat in those countries.

There has been a steady increase in the use of the modern wheats since their first introduction. Initial adoption was very rapid in a number of countries of Asia, reaching nearly 40 percent in India by 1970, and adoption has continued gradually since then. By 1983, India, Bangladesh, Nepal, Pakistan, Kenya, Argentina, Colombia, Mexico, Lebanon and Saudi Arabia all had over 80 percent of their wheat area in semi-dwarf varieties. Clearly, however, 100 percent is the limit to the proportion of area that can be covered. After that, continued improvements in the yield potential or pest resistance can provide continued yield improvements, but those advantages would not be reflected in aggregate data such as those shown in Table 6.2.

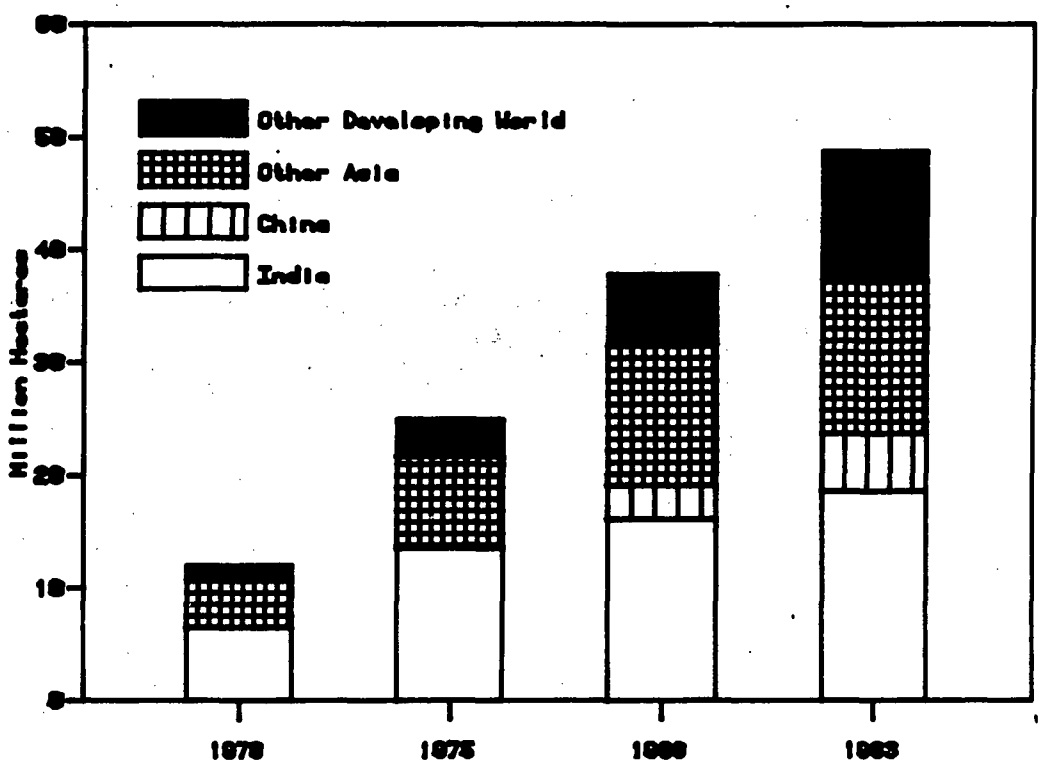
These semi-dwarf varieties have spread widely and, contrary to popular perceptions, are grown under dryland or rainfed conditions as well as with irrigation. Data to illustrate this are not available for many countries but some illustrative examples exist. In Bangladesh the area of semi-dwarf wheat increased from 20,000 ha in 1971-74 to 500,000 ha by 1980-81. There are no statistics on the exact area of rainfed semi-dwarfs but, even if it is assumed that all of the irrigated wheat area is devoted to semi-dwarfs, the minimal area in rainfed semi-dwarf wheat in Bangladesh was around 300,000 ha by 1980. Between 1980 and 1983 the global area in semi-dwarf wheats increased by over 10 million ha, with much of this increase occurring in China.

Table 6.2. Area Under Semi-Dwarf Wheat, 1970 and 1983.

Country	1970		1983	
	'000 ha	%	'000 ha	%
China	14.7	0.1	5126.0	17.8
India	6480.0	39.0	18550.0	80.1
Other Developing Asia	3458.6	40.1	7797.1	68.8
Afghanistan	232.0	10.5	400.0	13.3
Bangladesh			498.0	96.0
Nepal	98.3	49.2	377.6	92.1
Pakistan	3128.3	50.3	6521.5	88.2
Sub-Saharan Africa	69.8	5.0	556.3	52.1
Ethiopia	60.4	5.7	384.0	51.2
Kenya	7.9	5.3	83.8	72.9
Nigeria	1.0	33.3	10.0	71.4
Sudan		0.0	46.5	35.8
Tanzania		0.0	10.0	43.5
Zimbabwe	0.5	4.2	22.0	62.9
Latin America	794.5	10.8	8878.0	82.5
Argentina		0.0	6490.4	95.0
Bolivia	1.9	2.5	6.0	9.2
Brazil	56.1	3.1	826.5	43.0
Chile	61.2	8.3	329.7	70.0
Colombia	9.2	21.9	42.8	95.0
Ecuador		0.0	8.0	36.4
Guatemala	11.9	29.8	39.9	95.0
Mexico	651.9	88.1	942.5	95.2
Paraguay	2.1	6.6	6.0	8.0
Uruguay	0.2	.0	186.2	62.1
Middle East/ North Africa	1144.4	5.0	7690.3	33.8
Algeria	140.0	6.1	400.0	30.8
Egypt	0.0	0.0	306.2	53.7
Iran	63.0	1.3	891.7	14.7
Iraq	125.0	6.1	600.0	50.0
Libya	4.8	2.9	97.3	34.8
Morocco	90.0	4.6	721.6	36.5
Saudi Arabia		0.0	288.0	100.0
Syria	28.6	2.1	601.5	46.6
Tunisia	53.0	4.8	344.0	37.0
Turkey	640.0	7.4	3440.0	38.9
All Developing Countries	11962.0	14.0	48597.7	49.7

Source:Adapted from Dalrymple(1985).

Figure 6.3
Area under semi-dwarf wheat, 1970-1983.



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6.3.2 Rice

As with wheat, the first rices developed by IRRI using Taiwanese and other parents were a radically different type of plant from those traditionally grown. They were much shorter and would flower and produce grain any time during the year in the tropics, being non-photoperiod sensitive. The first group of these varieties (including IR8) was approved by the Philippine government for use by farmers in 1966 and, by 1969, three other varieties had been approved (IR5, IR20, and IR22). They and other genetic material from the international centers were made available to rice growing countries and, by 1972, a total of 19 IRRI-derived varieties (including the important IR36) had been named by national authorities. The rice research programs of CIAT, IITA and WARDA have produced a series of varieties named by national authorities, mostly in the regions in which they concentrate. By 1984 nearly 300 rice varieties had been named by national programs in 39 countries derived from or produced by the rice programs of the centers in collaboration with national researchers.

There has been a steady increase in the area planted to international center-related rices since their introduction in 1965. By 1975 they had spread to over 24 million ha, excluding the area of similar but independently developed rices in China (Figure 6.4). IRRI established working relations with China in the 1970s and, by 1983, IRRI varieties were being extensively used by Chinese researchers to produce the newest and highest yielding hybrid rices for that country. Even excluding these hybrids developed in China, center-derived rice varieties had spread to over 42 million ha by 1983, covering 70 percent or more of the rice land of Indonesia, Philippines, Sri Lanka, Senegal, Colombia, Honduras, Mexico, Nicaragua, Peru and Venezuela.

Table 6.3. Area Under Semi-Dwarf Rice, 1970 and 1983.

COUNTRY	1970 '000 HA	1970 %	1983 '000 HA	1983 %
China	26848.0	77.3	32265.2	95.0
India	5588.0	14.8	22180.0	54.1
Other Developing Asia	4281.5	10.0	19734.1	42.4
Bangladesh			2628.5	24.8
Burma	200.0	4.2	2370.1	50.4
Indonesia	1072.2	13.0	6626.9	72.8
Laos	53.6	6.0	9.7	1.4
Malaysia	164.6	23.3	254.8	36.4
Nepal	67.4	5.6	478.9	37.1
Pakistan	550.0	4.6	915.7	45.3
Philippines	1565.4	49.3	2757.0	83.5
S. Korea	2.7	0.2	418.6	34.1
Sri Lanka	73.6	11.2	749.7	81.0
Thailand	30.0	0.4	1200.0	12.8
Vietnam	502.0	20.1	1324.2	50.0
Sub-Saharan Africa	40.9	4.1	241.9	14.8
Camaroon			7.9	35.9
Ghana	36.8	89.8	35.0	43.8
Ivory Coast	2.1	0.7	32.7	7.1
Nigeria	1.0	0.4	60.0	10.0
Senegal	1.0	1.1	72.4	96.5
Sierra Leone			33.9	8.5
Latin America	252.4	4.2	1831.7	27.8
Argentina			27.3	33.7
Brazil			729.1	14.3
Colombia	41.0	17.4	364.3	91.8
Ecuador	15.7	10.5	40.3	53.1
Guatemala			3.5	29.2
Guyana			43.5	59.5
Haiti			11.0	22.0
Honduras	0.9	4.7	21.4	89.2
Mexico	123.3	66.6	154.2	83.4
Nicaragua	9.1	33.7	37.1	78.9
Panama	40.6	31.2	55.2	69.0
Paraguay	0.2	1.5	21.9	64.4
Peru	16.9	12.8	140.7	74.1
Surinam	4.7	13.1	48.7	69.6
Venezuela			133.5	79.9
Middle East/ North Africa	2.1	0.3	80.7	11.0
Egypt	2.1	0.4	20.7	4.9
Iran			60.0	19.2
All Developing Countries	37012.9	30.1	76333.6	58.5

Source: Adapted from Dalrymple(1985).

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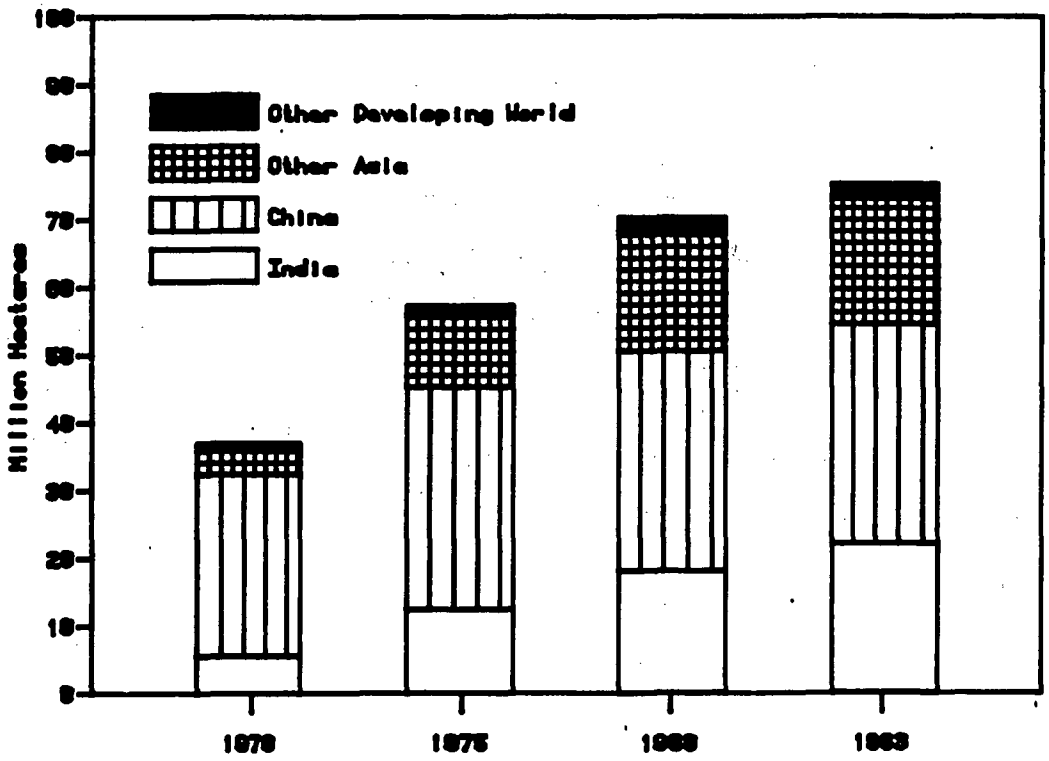
Figure 6.4
Area under semi-dwarf rice, 1970-1983.



Including the Chinese area, semi-dwarfs had spread to over 75 million ha or 57 percent of rice area in the developing countries by that year.

6.4 Centers' Breeding Approaches

6.4.1 Plant breeding and productivity

There are three components of technical advance in crop production: environmental (E), genetic (G) and interactive (G x E). The E component is mainly husbandry (tillage, weed control, disease control and so forth) but it contains also a social element, namely the acceptability of a variety to the consumer. The G component is plant breeding, genetic advance that enhances yield, disease resistance (best thought of as protection of yield), adaptation to local environments and/or cultural practices, and quality as perceived by consumers, usually through markets. The GE (interaction) component relates to the differential performance of genotypes (varieties) in diverse environments, both physical and social. It may be exemplified by pairs of contrasted varieties that differ in, for example: yield in sites contrasted as to length of growing season; yield in the presence/absence of a disease; yield in the presence/absence of different cultural practices; and market adaptation including preferences, for tastes, textures, colors, cooking and processing characteristics.

The socio-agricultural environments of crops vary in both space and time. In space, they range from fairly uniform over quite large areas (as with IRRI paddy rices in which varieties do well over large areas and suit large markets) to very small (as with many tropical food crops, in which physical environments and local markets may be extremely restricted).

Environments vary in time, too, maybe imperceptibly over short periods but cumulatively very greatly. North temperate cereal yields have roughly doubled over the past 40 years, partly as a consequence of enhanced husbandry (with fertilizers, herbicides, machinery, disease and pest control as major components). Genotypic adaptation to such secular changes is no less necessary than it is for spatially distributed variation. Historically, indeed, the semi-dwarf small-grain cereals and the temperate maizes tolerant of high-density planting, developed in association with the changing husbandries. The modern wheats and rices represented an exactly analogous exploitation of a grand scale GE effect. Historically, in north temperate agriculture, it is unclear whether the changing husbandry pulled the breeding of adapted varieties as a response or whether the breeding evoked the husbandry (or a little of each). In the case of semi-dwarf rices and wheats, there is no doubt that the G, E and GE parts were generated collectively as "packages". Whatever the history (chapter 8), the importance of the GE effect is plain - neither varieties nor husbandries could have succeeded on their own (Simmonds 1981).

Most of the literature of GE effects in plant breeding relates to yields, and this character is indeed all-pervasive and often dominant in breeding programs. But the final judgement of value of a variety is based upon "general worth", a complex character that includes socio-economic features as well as yield, often with tradeoffs between components: a low yielding variety may be acceptable if it does not need to be sprayed or is especially early or drought-resistant or has exceptional quality; and a poor quality variety may be acceptable if it is very high yielding (as IR8 rice, with its "chalky" grain was widely accepted in Asia). Food-crop breeders, especially breeders serving myriads of tropical small-scale farmers in

exceedingly diverse agricultural and socio-economic circumstances, cannot afford to exclude the socio-economic component in the environment encountered by a plant variety. For them, GE interactions and the intrusion of explicit socio- economic features into "general worth" are all-pervasive realities. The more diverse the socio-agricultural environments to be served, the more important GE effects are likely to be. Plant breeding, in short, is, of its nature, highly locational specific. Really widely adapted varieties are only likely to appear in relation to exceptionally uniform environments: diverse environments demand diverse varieties.

6.4.2 Issues in operational breeding work

Operational features of the centers in relation to crop production include several common features. The effort is divided roughly half-and-half between breeding (G) and husbandry (E) studies. Breeding authority is fairly highly centralized, with a "lead center" for a particular crop, working with outstations and collaborating institutes in other territories. The general style is "the package" of the modern variety plus the kit of treatments to go with it. This implies at least some degree of acceptance of the notion that substantial advance (on the model of earlier successes with modern varieties) must depend upon G + E + GE effects jointly. Breeding and selection take place largely on the experiment stations of the world under relatively good conditions of moisture, fertility, weed control and pest and disease control. In short, material is generally selected under rather high levels of inputs which for many important environments, such as temperate wheat lands, may be quite an appropriate procedure. Occasional efforts partly to mimic farm conditions are made, however (e.g., CIAT grows beans on maize at diverse spacings), and some low-input trials are done (e.g., CIMMYT maize). Sometimes, "shuttle breeding" (a CIMMYT term) is practised, partly to

accelerate the program by taking two or more generations a year but also to diversify the selection environments in hope of generating wide adaptation among the products.

The products of breeding emerge as numerous lines/populations/clones, all showing some promise in the original selection site(s), which are then subjected to multilocational testing in diverse sites, by a center itself, by collaborating centers and by national agricultural research systems. The intention is that such testing shall reveal not only widely adapted varieties but also local adaptation (i.e., shall exploit a GE effect) where it exists. Any potentially good varieties so revealed are then freely available for local exploitation by any appropriate means that presents itself. Trial results, returned to the breeders, help to guide future activities. Multilocational testing is operationally feasible for most seed propagated annual crops but for clonal crops is severely obstructed by quarantine regulations. There has been some rather restricted exchange of cassava material. If the CGIAR system handled clonal perennials (in effect, it does not), the problems and delays would be even worse.

The genetic base of breeding stocks is, with varying degrees of commitment to the idea, kept wide in the hope of generating enough variability among the products to meet the unforseeable GE effects that become apparent in the form of local adaptation. Also with a varying degree of commitment, breeding in the centers is linked to genetic resource conservation work, a natural starting point for a wide breeding base and a natural source for specific genes (especially disease resistances).

The principle of development is widely accepted. That is, varieties picked by national systems from multilocational trials can be used either as local varieties or as parents in national breeding programs, or as both. In parallel, a center can and does respond to expressed national interest in particular parental combinations or plant characters. The expectation is that, in the longer run, plant breeding will largely devolve to national systems (presumably leaving the centers to genetic resources work, population development and training activities).

There is pressure on breeders (as there is on other research people in the centers) to produce "practical" results. This is a sociological fact that has several undesirable side effects, notably: an oft-noted tendency to glossy publicity, a failure to make critical contributions to plant breeding ideas, and a tendency to take some quick and easy but not necessarily best ways.

6.4.3 Criticisms of centers' breeding strategies

The CGIAR was probably founded in the hope that more green revolutions would follow the achievements of the Ford and Rockefeller Foundations through modern wheats and rices. They did not; nor were they to be expected because the biological and social preconditions were simply not there. Tropical foodcrop agriculture (irrigated wheat and rice farming excepted) is mostly a complex mosaic of rather local physical environments, cropping patterns, cultural practices and socio-economic circumstances. The centers (and the national systems with which they collaborate) have, therefore, had to settle down to the ordinary hard work of agricultural research, of hard-won stepwise changes in husbandry and varieties. "Breakthroughs" are not, or are but very rarely, in prospect.

Criticisms may be made of plant breeding in the centers despite the large scale and high professionalism of much center breeding. Programs have a tendency to be over-centralized. It may not be sensible merely to produce flows of diverse materials through one or a few environmental "bottlenecks" and hope that the products will either be widely adapted or capable of meeting many demands for specific local adaptation. There is a limit to the number of diseases that can be coped with in one place. More generally, centralized decisions as to parents and breeding plans are certain to be wrong for most places most of the time, unless GE effects can be ignored, which they cannot.

The natural short-term response to a troublesome disease is to use any available major gene resistance, usually a pathotype-specific vertical resistance (Simmonds 1983). This may work for airborne pathogens, but it is hazardous. A new pathotype may (and probably will) emerge and the vertifolia effect of Van der Plank may make the last state worse than the first. To breed in such a way as knowingly to incur the risk of renewed epidemics in food crops can surely not be correct in the long run, even if it is sometimes inescapable in the short run. Yet there seems too little consciousness of the alternative (horizontal resistance) or of the need for back-up breeding to construct horizontal resistance. Perhaps the consciousness is growing and it has to be said that many temperate plant breeding programs seem not very aware either. Rich countries, however, can stand epidemics that would be disastrous for subsistence farmers.

If the object is to breed varieties for small-scale farmers employing low inputs, a procedure of selection under high input conditions on experiment stations is likely to be self-defeating. It is not good enough simply to do odd trials, later on, at low inputs if parents have been chosen and progeny

selected in contrasted environments. The failing is a failure of perception of the force of GE effects. Most plant breeders in rich temperate countries do not face this problem because they are breeding for high-input agricultures. The practical problem before the centers, of making selection environments more realistic, will not easily be solved. Some center breeders are conscious of the problem and are trying to attack it; others are not.

Related to this preceding point, but rather wider, is the matter of farming systems perspective. Plant varieties are bred for "general worth" in particular socio-agricultural environments. If breeders misperceive the environment, their varieties are unlikely to do well. Breeders cannot know too much about the agricultures they seek to serve, but that knowledge is not acquired on the experiment station. Substantial proportions of maize in tropical America and of sorghum in Africa are both food-grain crops and supports for cash crops (beans and yams, respectively). Farmers want tall, strong, widely spaced cereal plants, not small, slim closely spaced ones. CIAT bean breeders select their beans on maize but maize or sorghum breeders seemingly do not select their cereals with cash crops hanging on them. Perhaps they should? Sufficient attention to the main agricultural reality of dryland barleys grazed by sheep in the spring is only slowly being paid by breeders at ICARDA.

There are perhaps too many gimmicks related to public relations activity and the need for "breakthroughs", to the over-practicality of much of the work, and to intolerant scepticism of criticisms. CIP's potatoes from "true seed", for example, may fall into this category. Some observers believe that there may be few actions that could confer greater benefit on the centers than the banning of glossy reports and other sub-literature, and the promotion of

orderly scientific publication in properly referred journals (for all their imperfections).

6.5 Change in Food Production

The modern, semi-dwarf varieties of wheat and rice give more or less higher yields than traditional types under both experiment-station conditions and most of millions of hectares on which they are being grown by farmers. There are, clearly, some farmers' conditions under which they are less productive than traditional varieties, and there farmers continue to grow traditional varieties. Those farmers who have done so have felt that they should grow the new varieties because they are perceived (through their observation and perhaps also extension propaganda) to be more productive than other available varieties. Their contribution to food production depends on how much yield advantage they have over traditional varieties. While it is clear that they must have such an advantage, or else farmers would not grow them, it is not clear exactly how large that advantage is. Data bearing on the question are examined, with results reported in the next two subsections.

6.5.1 Wheat grain yields

The initial semi-dwarf wheats raised the yield potential under experiment-experiment station conditions from 4 t/ha to the 7-8 t/ha range. Since their first development and release in the early 1960s, their yield potential has gradually been increased to the 8-9 t/ha range. The exact degree of yield advantage over "traditional", tall varieties is no longer an issue for much research attention because of the degree to which the new varieties have replaced the old. Data are available that illustrate their continued improvement: during the three-year period 1980-82, international

comparisons of the most advanced wheat lines ("Veery" lines) with the best locally grown varieties (i.e., the "local checks", most of which were also semi-dwarf), showed that the Verry lines outyielded the best local check variety by about 10 percent on average, and outyielded the best local check in 65 percent of the developing country locations (CIMMYT 1983, p. 19). One indication of the value of these lines is that, by 1984, twelve varieties based on these lines had been named by national programs in Chile, Mexico, Portugal, Pakistan, Paraguay, South Africa, Spain, Zambia, and Zimbabwe.

Few recent yield comparisons of semi-dwarf and traditional wheats grown in farmers fields are available, but earlier research suggested that yields of the semi-dwarf wheat varieties give between 30 percent and 200 percent higher yields than traditional varieties. Statistics from India, covering the period between 1966 and 1973, when adoption increased to over 50 percent of area, showed that the new wheats give yields "from less than two times to more than three times as high as traditional varieties" (Dalrymple 1975, p. 25). Farm level data from six large-scale studies in India showed that the new wheats gave average yields 80 percent higher than the local varieties (Vyas 1975). An analysis of farm-level data from Tunisia showed that farmers growing the semi-dwarf varieties with the average level of inputs had 20 percent higher yields than farmers growing traditional varieties using the same level of inputs (Gafsi 1976). Similar farm-level data for Turkey showed that farmers growing the new varieties had 40 percent higher yields than those growing other varieties (Demir 1976). The absolute yield advantage of the new varieties over the old in these studies ranged from 350 kg/ha in Tunisia to 1100 kg/ha in India, suggesting that an average difference of 500 kg/ha between new and old varieties, as grown by farmers, would be a conservative estimate.

6.5.2 Rice grain yields

The yield advantage of modern varieties of rice can be estimated from some national statistics in a few countries that keep such statistics. Between 1968 and 1977, the modern varieties gave an average of 100 percent higher yield than traditional rice varieties in India; in Bangladesh they gave 160 percent more than local varieties; in the Philippines and Indonesia they gave 30 percent more than the traditional varieties (Herdt and Barker 1985). These differences may reflect, in part, the fact that the new varieties were initially grown under relatively favorable, high-quality land conditions in India and Bangladesh so that the differences between the yields with new and old were large, while in the Philippines and Indonesia, the varieties were suited to a much broader range of conditions, with a smaller average yield advantage.

Farm-level comparisons of new and old varieties have been carried out in many Asian rice growing countries. One review of farm-level studies found that the yield advantage of modern varieties varied from 10 to 158 percent (Dalrymple 1977). Another review of studies covering 28 locations showed that the new varieties outyielded the traditional ones by 10 to 100 percent, averaging 40 percent higher yield (Herdt and Barker 1985). On this basis 600 kg/ha would be a conservative estimate of the average yield advantage of modern rices over the traditional. Farm yields of rice include the inedible (but still valuable as fuel) hulls, which account for about one-third, so the yield advantage converts to 400 kg/ha of edible cereal grain.

6.5.3 Production advantage

New varieties are usually grown under better land conditions because they have the potential to give higher yields if provided with good growing conditions while the old varieties do not respond as much to advantageous growing conditions. For this reason, most of the irrigated rice and wheat land is planted to new varieties and, for the same reason, the new varieties are grown with higher rates of fertilizer, and with greater attention to weed control by farmers. In many cases, these are provided from additional organic manures and additional family labor, as, for example, in India, China and Bangladesh. It is also clear that, both from experimental evidence and farmers' experiences, application of chemical fertilizers is highly productive and profitable on these varieties and, because governments want the increased food that can be produced using them, fertilizers are made available and applied. In areas where labor is plentiful, additional labor is used for weeding but, where it is less available or more costly, farmers seek alternative means of weed control, through cultivation or herbicides. The idea that modern varieties "require" more inputs than the old ones is not substantiated -- they respond to higher levels but do not require them. Equivalently, while modern varieties respond profitably to higher input levels, the yield advantage is not lost if for any reason these inputs are not provided.

These additional inputs contribute to production, so the entire production increase cannot be attributed to varieties alone but, on the other hand, without the productivity gains available from the combination of varieties and inputs, there would have been little reason to use higher levels of inputs. Thus, it does seem reasonable to attribute the value of extra production, less the costs of extra inputs, to the new varieties.

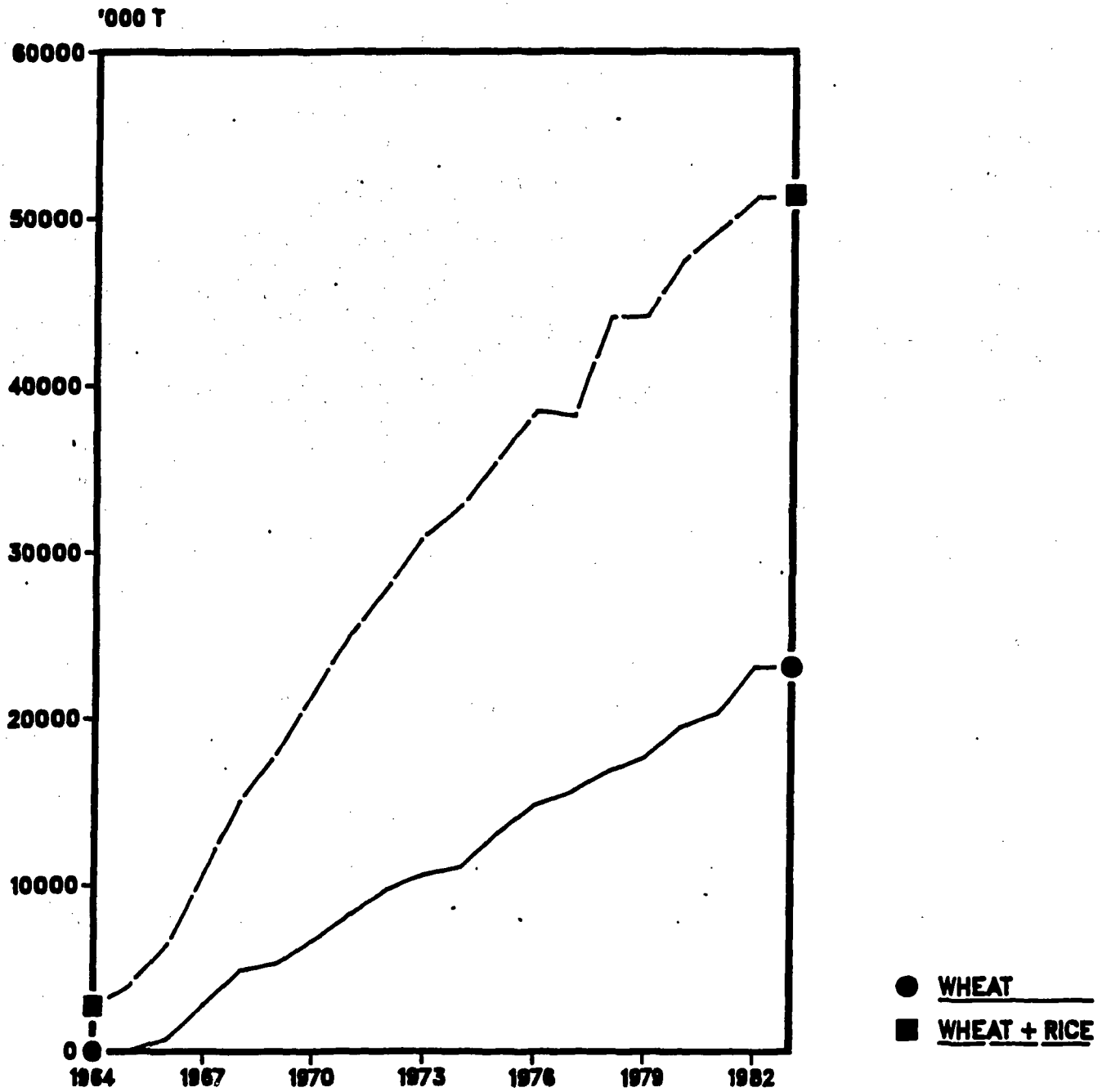
By 1965 and 1970, farmers in the developing countries other than China adopted modern wheats on approximately 11 million ha and modern rices on an estimated 10.3 million ha; with China included, the area of semi-dwarf rice was 37 million ha. The additional food production made possible by the new semi-dwarf varieties in 1970 was about 21.5 million tons (Mt) of grain (Figure 6.5). By 1983, the latest year for which data are available, the area of modern wheat, excluding China's area, was 43.6 million ha, the area of modern rice outside China was 42.9 million ha and the increased food production made possible from these varieties was 38.9 Mt. Including China, the modern wheat varieties were planted on over 48 million ha in the developing world in 1983, modern rices on over 75 million ha, and the estimated increase in food production amounts over 50 Mt, enough to provide the average grain consumption levels for over 500 million developing country people.

6.5.4 Farm-level productivity gains

Governments have limited power and they choose to take even more limited power to encourage farmers to use given production technologies, so widespread adoption of a technology is evidence that farmers find it preferable to the available alternatives. Conversely, the lack of adoption indicates that, under farmers' conditions, particular technology is no better than available alternatives, perhaps because of the lack of some key complementary inputs or of a ready market, or for some other reasons not strictly related to the characteristics of the technology.

Figure 6.5

ESTIMATED ADDITIONAL FOOD PRODUCED BY SEMI-DWARF WHEAT AND RICE IN ALL DEVELOPING COUNTRIES



Feature: Rice in Luzon, Philippines

Two samples of rice farmers in the most advanced intensive producing areas of Luzon, Philippines were interviewed, one in 1965 and one in 1966, before the introduction of semi-dwarf rices and again at 4-5 year intervals until 1982. The proportion growing modern varieties of rices increased from none in 1964 to an average of 63 percent in 1970, 76 percent in 1974, and over 95 percent in 1981-82. The proportion of the sample farmers using fertilizer on their rice increased from 60 percent in the initial year to over 95 percent in 1982, the proportion using insecticides increased from 31 percent to 92 percent, and the proportion using herbicides increased from 12 percent to 74 percent. Thus these data show that adoption of modern varieties occurred more rapidly than adoption of other technologies, even though the process had started earlier for the other technologies.

Over the period, the average cost of the material inputs increased from 53 pesos to 988 pesos per ha, but inflation accounted for much of the increase in costs and returns over the period. For example, the price of rice increased from 0.43 pesos per kg in 1964 to 1.27 pesos per kg in 1982. Converting all values to their equivalent in terms of kilograms of rice makes it possible to abstract somewhat from the price changes to see the effect of the changes in inputs used and the effects of the technology. The choice of the major staple food as the deflator is somewhat arbitrary although convenient. Given that it has been subjected to price reductions due to increases in supply it is not a conservative deflator (although it is more so than, say, hand calculators or computers) but is indicative and, it is believed, instructive.

Output averaged 2280 kg/ha in 1964 and increased to 4200 kg/ha in 1982. The cost of the material inputs in terms of rice equivalent increased from 120 kg/ha to 780 kg/ha. As a result, the quantity of rice left after paying for the inputs used with the new technology increased from 2160 kg/ha to 3240 kg/ha. Of course, farmers have other costs — land, labor and capital services — which they purchase, so the entire amount left after paying for inputs is not profit, but clearly the output of rice increased by far more than the cost of inputs.

When all paid out costs are deducted from production, the amount remaining (farm family earnings) reflects what the farm family can consume or sell and convert into cash income. Two major changes that increased farm family earnings were higher yields and lower land rents resulting from land reform. Increased payments for current inputs, hired labor and hired machinery reduced cash earnings. The net result was an increase from an average of 860 kg/ha in 1966 to 1570 kg/ha in 1982, representing an almost doubling in the quantity of disposable rice available to the family.

END FEATURE

It has been argued occasionally that the inputs used with "green revolution" technologies are so costly that their use leaves farmers worse off. If the technology is so widely used as to reduce the market price by more than it reduces unit costs, farmers as a group may be worse off, or in the more usual case, non-adopting farmers are made worse off by even modest price reduction (see section 6.5.5). But it is difficult to see how any farmer would willingly continue the use of new technologies if they raise unit costs in the first instance. Because every situation is different and because there are relatively few studies that provide such details, it is impossible to give comprehensive data on this issue, but the case of Philippine rice farmers discussed in the accompanying feature is instructive.

Where input prices of modern inputs have increased, farmers can make the choice not to apply such inputs. The real costs of inputs used with the new technology have not generally increased on the world market. While it is true that world fertilizer prices increased sharply between 1973 and 1975, thereafter they declined sharply, and in 1983 were just about equal to their 1976 level in real terms (World Bank 1984). On the other hand, these prices are in US dollar terms, and countries whose currencies have devalued relative to the dollar and which depend on the export of commodities which have experienced depressed prices in recent years, have had increasing difficulty paying for imported inputs in the 1980s. They would be in still more difficult positions if they had to import the food they are now able to produce with the new technologies available.

One possibility, which the concerned countries hardly rate as a real option, is to cease importing inputs and to produce using only domestically available inputs. The problem is that there are no technologies for growing

food crops without supplying plants their essential nutrients, often from mineral fertilizers that may not be manufactured locally. The suggestion that plant breeders at the international centers should produce varieties that give high yields without additional nutrients is unrealistic. There may be ways to make the process more efficient, and these are being pursued; but a minimum of nutrients will have to be obtained from some source ("organic" farming?) if productivity is to be sustained.

6.5.5 Implications of widespread adoption

When many farmers adopt a new technology, the total availability of the commodity may increase at a more rapid rate than demand, with the result that the commodity's price tends to fall. This mechanism transfers benefits to consumers of the product and, in the cases of modern wheat and rice varieties, has been important for providing substantial benefits to poor consumers, as is discussed in chapter 8.

The fall in the price of commodities resulting from widespread technical change is different from a fall in prices caused by large, subsidized imports, or government rationing and price controls. In the case of the latter two policies, there is no way farmers can avoid the effect of the fall in prices to obtain a constant or increased return to their family resources. With technical change, however, costs of production per unit fall and so, even if prices fall, it may still be possible for farmers to achieve adequate returns. Indeed, some may be encouraged to adapt the new ways in order to maintain incomes as prices decline.

Some observers automatically associate labor-displacing machinery with the idea of modern technology. But in the case of the new wheat and rice

varieties, there is no more reason to use machinery in production than with the varieties they replace, and where machinery has accompanied the adoption of new varieties, its use has been motivated by other reasons. There is some incentive to use machinery for harvesting and postharvest operations if farmers have the opportunity to use their land for a second cropping season. The machines may help to harvest more quickly and thus to facilitate planting the next crop. However, the evidence suggests that machinery is not necessary for increasing output, and that its absence has not slowed the rate of increase of food production.

On the other hand, there is considerable evidence that the introduction of new wheat and rice varieties has been associated with increases of labor use on the order of 25 percent for a single crop in many areas, much of the additional labor being hired. However, even where, in aggregate, labor demand is increasing, certain categories of labor may be disadvantaged, especially where modern technologies have been associated with changes in the organization of production in conditions of gender-specific task allocating and have led to increases in unpaid female labor or decreases in remunerative work opportunities for women. There is also evidence that the new varieties have allowed a substantial increase in the proportion of land that is double cropped. A dramatic case is that of wheat in Bangladesh.

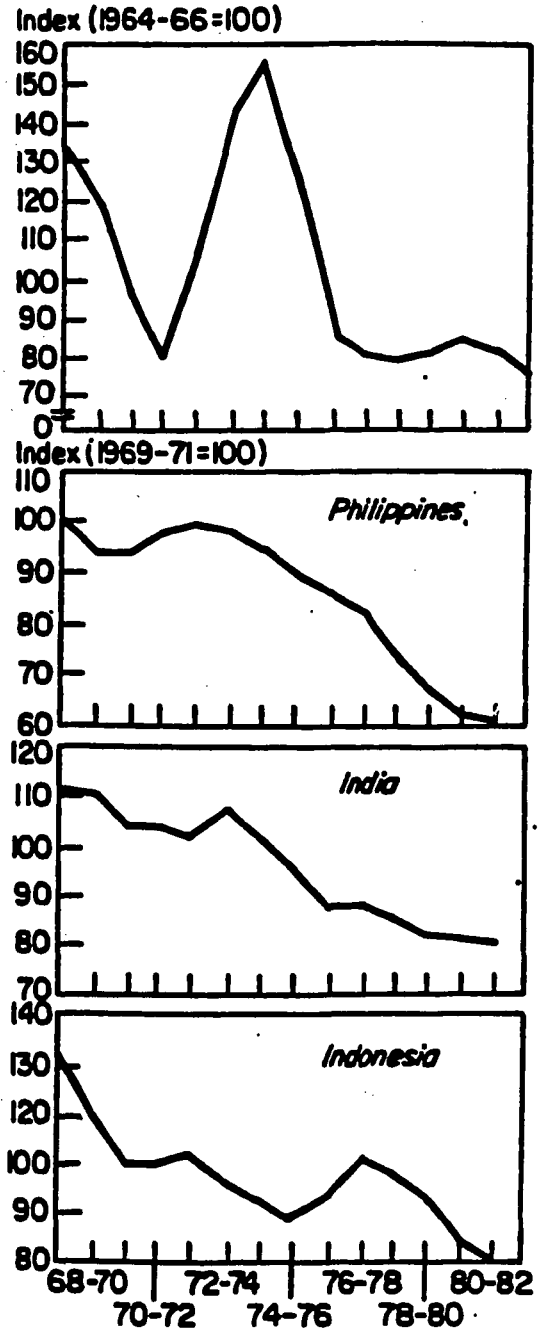
Prior to the availability of short-duration adapted varieties, about 100,000 ha of land were planted to wheat each year in Bangladesh. Since 1975-76 wheat production has increased at the astounding rate of 50 percent per year, largely on land that had previously remained in fallow during the winter season. By 1981, over half a million hectares of land were planted to wheat in the country and over 1 Mt of wheat were being produced annually. Because

much of this wheat was planted on land that had been in fallow, the labor needed for its cultivation represented a net increase in employment.

One of the clearest predictions of economics is that, other things unchanged, the price of rice and wheat should be expected to decline in the face of widespread technological change such as has been experienced with the semi-dwarf varieties. Wheat prices in many developing countries are closely related to world wheat prices because of large imports, but rice prices are isolated from the world market in many countries. Figure 6.6 shows some data on domestic rice prices in a number of Asian countries where technical change in rice has been rapid. There has been a reduction in domestic prices as a result of the technical change. Consumers are able to obtain their food requirements at lower costs than would otherwise have been the case. This is a major benefit of technical change (it is discussed more extensively in chapters 8). Some farmers who have used the new technologies are able to offset the lower prices received by their higher output and consequently lower costs per unit produced. Some other farmers growing the same products who have been unable to adopt the new technologies are worse off because they receive lower prices but have no change in costs.

These and other effects of widespread adoption of new varieties quickly become difficult or impossible to follow through an economy because they interact with other changes that are also occurring (chapter 8). Rapid population growth may drive up food needs and labor supply, changes in world prices of an export commodity may increase the demand for inputs which may raise their prices, a weak industrial sector may have little demand for labor so that more workers must seek employment in agriculture, distribution of income generated by new industrial activities may be highly concentrated

Figure 6.6



Trends in real world rice price and in rice price to consumers in selected, formerly rice importing, countries.

thereby generating strong demand for imported goods and little effective extra demand for agricultural products (chapter 1). In the face of these and other changes it is challenging indeed to trace clearly the complex changes caused by changing technologies in agriculture in general and by those that have some association with a center in particular. The economic and social impacts consist of positive and negative elements with gainers and losers often to be found in different parts of the economy and the agro-ecosystems that are farmed. A socially sensitive policy on technological change in general, and on agricultural research in particular, can go far to minimize the negative effects, especially on those who can least afford to lose. Many of the possibilities relevant to the poverty-oriented work of the centers are noted in chapter 8.

6.6 Change in Stability

The types and severity of risks confronting farmers vary greatly according to the farming system, and to the climatological, policy, and institutional setting. Nevertheless, agricultural risks seem to be prevalent throughout most of the world. They are particularly burdensome to operators of small farms in developing countries, and hence the impact of adopting new technologies is of concern. These farmers, typically being averse to risks, seek to avoid them through various managerial and institutional mechanisms. For example, they may diversify their crops, favor traditional farming techniques using fewer modern inputs, and enter into sharecropping arrangements.

The growth of foodgrain production in recent decades has in most countries been accompanied by increases in variability at the national level (dispersion about trend). For example, in India, the variance of national

cereal production around trend increased by 240 percent between the 1952/3 to 1964/5 period prior to the introduction of semi-dwarfs and the 1967/8 to 1977/8 period after their introduction. Sixty percent of the increase was due to increased variability of planted area while 40 percent could be attributed to increased yield variability (Hazell 1984). Increases in yield variability appear to be related to greater price and rainfall variability and more erratic supplies of electricity for irrigation as well as changes in varieties. In many biological systems variance is positively related to mean output so that some of the increase on variance will be an automatic concomitant of increase in mean yield.

Increased yield correlation for foodgrain production between regions in other countries, including the industrial countries, is also apparent for rice, wheat and maize (Hazell 1985). The changes are less pronounced in developing countries than in the U.S.A., and they may result from economic as well as technological factors. However, to the extent that they arise from a narrowing genetic base, unless steps are taken to cultivate a wider diversity of genotypes, the problem could become more pronounced in these countries in the years ahead. The problem may be aggravated further as opportunities for exploiting new arable land and irrigation become more confined, and production growth depends increasingly on yield-improving technologies.

Since much of this variability is unpredictable for all the economic agents involved, it increases risk. Should these changes increase the adversity of life among the poor, they are relevant to a wider assessment of the impact of the centers' contributions to production.

There is no question that the growth in foodgrain production made possible by semi-dwarf varieties has been desirable in most countries for meeting increases in demand and lowering prices. However, increased domestic production variability is usually reflected in increased market and price instability which, in the absence of government intervention, can pose difficult problems for low income people. It also increases the size of emergency food stocks that need to be carried within countries to ensure that consumption does not fall precipitately.

Some researchers (e.g., Barker, Gabler and Winkelmann 1981, Mehra 1981) have attributed much of this increased production instability to the modern variety and fertilizer based technologies, particularly in developing countries. The yields of crops grown with the new technologies may be more sensitive to weather and disease. Because higher levels of purchased inputs are used, their yields may also be sensitive to year-to-year variations in access to inputs use arising from frequent price changes and climatic variation, or from supply restrictions.

Mehra (1981) has provided some support for the view that new technologies for cotton and hybrid pearl millet have increased yield variability for farmers, particularly in arid regions with limited irrigation. Consequently, the potential importance of breeding for more stable yields if farmers are to continue to find new technologies attractive for adoption. This concern may be especially relevant for coarse grains in Africa and the semi-arid tropical areas of Asia where new technologies tend to offer less favorable increases in mean yields to compensate farmers for the possibly higher yield and investment risks involved.

The importance of the new technologies in increasing the variability of national foodgrain production is less clear than it might be because many other factors also contribute to variability at the aggregate level. Clarification is being sought, especially by concerned centers, and a conference organized by IFPRI in November 1985 addressed these important issues too late for inclusion in the present volume.

6.7 Coda

* Plant breeding is a time consuming process: existing varieties, breeders' lines, mutant stocks and land races are collected, studied and crossed. Early generations "segregate" in reaction to particular stresses. Plants are purposively subjected to a series of stresses thereby identifying resistant plants by screening. The process is time consuming because one season is required to grow each generation, and because screening for different characters is often carried out sequentially.

* After five to seven generations of selection pressure, a line may be ready for preliminary testing. Thereafter, advanced lines may be entered in trials in a number of locations. Additional time is required for national authorities to test and evaluate the suitability of materials for their conditions. The minimal time required is five to eight years between initiation of a crossing program, and identification of promising varieties. The research that led to the release of CIMMYT wheats in the mid-1960s, for example, began 20 years earlier in Mexico and elsewhere.

* Centers that began breeding programs in the late 1960s on field beans, cassava, cowpeas, chickpeas, tropical sorghum, pearl millet and tropical pastures had to begin by collecting germplasm and determining how the existing varieties could be improved.

* By 1984 over 200 varieties each of wheat, rice and maize related to center efforts had been released by developing countries; more than 20 developing countries had named a total of 96 bean varieties related to center research; 16 countries had named 63 cassava varieties developed in cooperation with the centers; 23 developing countries had named 61 center-related potato varieties; over 30 center-related sorghum varieties had been named by countries. These new varieties are all being produced by farmers and are contributing to food production in a noticeable way.

* Countries in Africa have named over 50 center-related maize varieties, countries in Asia nearly this number, and countries in Latin America nearly 100. These new maize varieties are estimated to have spread to over 6 million ha by 1984.

* Varieties of barley, cowpeas, chickpeas, pasture species, pearl millet, durum wheat, and pigeonpea have also been named by national authorities and are beginning to be grown by farmers in the developing world.

* The bulk of the increased food production resulting from centers' research has been from wheat and rice. By 1983 the international center-related wheat varieties had spread to an estimated 48 million ha of land in the developing countries. This amounts to nearly 50 percent of the total area planted to wheat in those countries.

* Excluding semi-dwarf varieties developed in China, center-related rice varieties had spread to over 40 million ha by 1983; including the Chinese area, semi-dwarf rice had spread to over 75 million ha of rice in the developing countries.

* New wheats probably give an average yield of about 500 kg/ha over old varieties as grown by farmers; 600 kg/ha is a similarly conservative estimate of the average yield advantage of modern rices compared to the traditional. Allowing for the inedible hull, this converts to 400 kg/ha of extra food grain. Including China, the modern wheat and modern rice varieties gave an estimated increase in food production of over 50 Mt to provide the average grain consumption level for over 500 million people.

* Variability of production is controversial to measure but, by most indicators, has increased along with the average levels of foodgrain production. There are implications for storage and trade policy as well as for plant breeders in their continuing quest for greater stability in varietal performance through resistance to pests and diseases and tolerance of other environmental stresses.

7 HUSBANDRY AND METHODS

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7 HUSBANDRY AND METHODS

7.1 Introduction

The goal of research at the centers, in their collaborative programs and in the national systems, is to develop improved agricultural technologies. Major impacts have resulted from improved germplasm, but methods and programs other than plant breeding are also important. Such research has resulted in diverse technologies that range from new machines, through better management of experiment stations and breeding programs, to methods of producing disease-free planting material. Only relatively few such technologies were in widespread enough use by farmers in mid-1984 to have generated an impact at the farm level. These provide the focus for this chapter's discussion.

The collaborative research on non-germplasm technologies is analogous to that discussed in the previous chapter. There are joint research projects between the national systems and the centers, and also between cooperating national systems. There are regional networks of researchers to move technologies and ideas between countries. Center staff posted in countries in institution-building projects are another common form of collaboration. Center prototypes or blueprints for machinery are adapted to local conditions by agricultural engineering programs in the national systems. In chapter 13 the contributions of centers in plant protection are discussed while chapter 16 covers farming systems and chapter 17 presents the results of research on machinery, so those types of technology are not dealt with in detail in this chapter.

It is more difficult to develop estimates of the impact of management technology than of germplasm technology. Quantitative data on the spread of these technologies and of their impact on output and productivity are seldom collected. In addition, the problems of attribution are even more difficult for many of these technologies than for varieties. For example, what portion of social benefits are attributable to center-related research on integrated pest management techniques that include using a pesticide developed by a company which a center tested and found effective, with management techniques promoted by national extension programs?

Another example of these difficulties is an area where the centers have had a major impact, namely crop management. In the early days of the green revolution, modern varieties were promoted along with a "package" of practices which were developed collaboratively between the international centers and national systems. These packages were supposed to give farmers maximal returns from the use of the new varieties. The packages were promoted through extension, and frequently also through large-scale production programs which included subsidies for the inputs and sometimes, credit. The precise packages recommended by governments were nearly always rejected by farmers because they were not ideally suited to their soil, climate, goals or market conditions. But the principal inputs in the package were accepted - the seed, much of the fertilizer, and some of the recommended management practices.

With the desire to quantify the benefits juxtaposed against the problems of quantification and attribution, some selected examples of the quantitative impact on output and productivity of some technologies other than germplasm are given. No attempt is made to estimate the aggregate impact. The criteria

for selecting examples have been (a) clear links of the technology to the centers, (b) sufficient adoption by farmers to detect an impact of the technology, and (c) a range of different types of technology.

7.2 Output Effects of Specific Innovations

7.2.1 Diffused light potato seed storage

The technique of diffused light storage of potatoes for seed use is based on the physiology of tubers. As has long been known, storage in natural diffused light instead of complete darkness will reduce sprout elongation, increase sprout numbers, reduce total storage losses, and allow a longer period of storage. This increases total yields because of improved seeding vigor and a greater quantity of seed potatoes. It can further increase farmers' incomes by allowing them to plant later or earlier and thus perhaps to harvest their crop during times of high prices. This system which has been promoted by CIP, is now being used extensively by farmers in Peru, Colombia, the Philippines, Sri Lanka and elsewhere. In surveys in these countries CIP identified 3000 farmers who were using this method of storage in 1984, but this surely is a considerable underestimate. The natural spread of this technology from farmer to farmer has been rapid in at least 16 countries including Colombia, Ecuador, Peru, Kenya, Tunisia, Sri Lanka, and the Philippines. This technique is also being used widely by government instrumentalities to improve their seed production programs.

The history of this innovation in its developing-country incarnation is instructive. It was preceded by 20 years of unproductive research on potato storage in Peru in which scientists tried to reduce shrivelling and rotting in storage. It was only because a social anthropologist from CIP asked farmers what their priority problems were that sprouting in storage was identified.

Moreover, shrivelling and rotting were not regarded by farmers as major problems. Scientists knew that diffused light reduced sprouting, and eureka, working with farmers as the innovators, in farm conditions, stores were built that used available materials and fitted in with traditional architecture, and now after a few years these practices have spread to at least 21 countries. All because someone asked the farmers, after 20 years!

The yield increase from using seed from diffused light storage in on-farm trials in the Peruvian highlands was from 8 to 20 percent. Trials in the Philippines and Colombia gave similar results. Yield increases were 57 percent in a trial on the Peruvian coast, and from 80 to 133 percent in Sri Lanka. On average, small-scale farmers in these countries store two tons of seed potatoes to plant one hectare. If the yields increase by 20 percent from, say, 10.5 t/ha, the increase in output would be 12,600 t of potatoes worth about $1 m. Adoption on 10 percent of potato area in the countries where CIP is actively promoting this technology, with the same assumptions about the base yield and increase, would result in over 1 Mt of additional potatoes, valued at about $100 m.

7.2.2 Seed potato technology

Programs to improve potato seed are being carried out in a number of collaborative programs between CIP and national research systems. The methods of improving seeds vary according to the local constraints. In Bangladesh, for example, it is mainly a matter of identifying when the insect vectors of diseases are serious and then identifying areas where seed potatoes can be grown to avoid infestation.

Methods were developed to improve the quality of the seed potatoes sown in the late crop in Tunisia. These methods consisted of: (a) desprouting imported seed and the earliest possible planting of the seed crop in the early season; (b) early harvesting of the seed crop and elimination of unhealthy tubers before storage; and (c) desprouting locally produced seed tubers before planting in the late season. Seed production increased from 64t in 1977 to 680t in 1980, and further to 880t in 1983. The higher quality seeds produced more main stems per plant. This doubled the yields per hectare in on-farm trials of the late season crop. An analysis of the program's total costs and benefits was conducted by CIP based on data from the national unit responsible for seed production with the results shown in Table 7.1. Unlike many seed potato efforts, this national project has continued to function effectively over an extended period.

Researchers in the national program in Rwanda (PNAP) followed a similar process of improvements. They selected and named in 1982 four late blight resistant varieties with yields of about 20 t/ha.

Rather than attempting to establish a sophisticated seed certification program, PNAP uses simple techniques to supply farmers with improved quality seed. Rwanda's seed production system is based on mass selection. Without post-harvest virus testing facilities, the system depends primarily on field observation of plant vigor and the proportions of healthy and diseased plants.

The seed program now produces about 250 t of seed per year of which about 200 t are distributed to seed multiplication projects throughout the country. PNAP does not multiply the older local varieties. About 50 percent

Table 7.1 Costs and benefits of the Tunisian seed potato program (000$)

	Program budget		Increased cost of seed	Total costs	Benefits	Net benefits
	International	National				
1976	90	24	0	114	0	-114
1977	90	24	7	121	36	- 85
1978	90	30	13	133	90	- 43
1979	90	30	26	146	182	36
1980	90	36	59	185	385	200
1981	35	42	85	162	544	382
1982	20	42	71	133	419	286
1983	0	54	66	120	502	382

Source: CIP, (1984)

of the seed produced and distributed is of new Rwandan varieties selected from genetic material introduced by CIP.

The result is an increasing number of Rwandan farmers with access to improved seed which gradually replaces old, degenerated materials. Production of improved seed is still significantly lower than current farmer demand for it. Yet, reports from seed projects and preliminary surveys indicate that about 7000 hectares, representing 18 percent of the total potato area, are now planted with seed originating from the national seed program. The average yield increase on farms due to use of improved seed is estimated at about 3 t/ha - a 40 percent increase over traditional seed.

An economic analysis indicates that, after a short start-up period, the seed multiplication program's benefits have far exceeded its costs. As of 1985, the internal rate of return of the program is projected to be 40 percent more than twice the return offered by most development projects in the country. Since the program is expected to continue operating at the same scale, the future rate of return is expected to be much higher. This is because costs will remain at about the same level while benefits increase significantly as cultivation of new varieties spreads. Giventhe slow virus degeneration rate, the multiplier effect of a small stock of clean seed is great.

7.2.3 Deep Vertisol technology

ICRISAT has developed a package of improved technological options for increasing output on deep Vertisols in some areas of semi-arid India. The package includes: (a) postharvest cultivation following the post-rainy season rabi crop; (b) land levelling and shaping, construction of field and

community drains and the use of graded broadbeds and furrows; (c) dry seeding before the monsoon: (d) use of modern cultivars and moderate amounts of fertilizer; (e) improved placement of seeds, and fertilizer; and (f) timely plant protection. Most of these practices are implemented with a bullock drawn wheeled tool carrier. This technology for deep (over 45 cm) Vertisol soils is called the broad bed and furrow system (BBF).

On four sites in three states, ICRISAT compared the new package with the traditional one in 1982-83. The new package cost about $70/ha more than the traditional technology and gave an average increase in profits of about $140/ha (Walker 1983). In 1982-83, ICRISAT measured the costs and returns of farmers' implementation of this package of practices against the local practices on about 50 ha in Maharashtra. Cost increases with the new package averaged $145/ha and profits increased about $50/ha compared to the traditional technology in that area, suggesting somewhat less advantage of the technology than in the ICRISAT tests.

The latter data may be taken as a conservative estimate of the unit impact of the technology because they are based on farmer trials, not those conducted by ICRISAT, and many farmers in India do not enjoy the same access as ICRISAT to needed inputs. The increase in profit is due partially to new varieties as well as the other components of the BBF technology which are the subject of the present chapter.

Some of the problems with the technology include the weight of the land levelling/shaping tool bar and the poor condition of bullocks at the time the work is needed, and inqualities in access to bullock draft power and credit to purchase the still-expensive equipment. It should be noted that the package

being tested deliberately does not include a weedicide, in order not to displace the opportunities for female weeders.

This system is being tested by national program researchers and extension workers in the states of Karnataka, Andhra Pradesh, Mahrashtra and Madhya Pradesh. In surveys taken at the on-farm verification sites, some farmers have indicated they will continue to use these technologies. The practice appears to have spread furthest in Karnataka and will spread more widely in the future in Karnataka, Madhya Pradesh and Maharashtra in a World Bank financed watershed development project. Observers in India estimated that, in 1983, it was being used on about 4000 ha of semi-arid rainfed land under the control of the respective state governments. This would have led to an increase in net profit of over $200,000 in 1983. The total area for which the technology seems well suited in India is estimated at 5 million ha. Increased productivity valued at $125m annually would be forthcoming if the technology were to be implemented on even half that area.

7.2.4 Blue-green algae/azolla technology

Azolla is an aquatic fern which grows in ponds, canals and rice paddies. Blue-green algae grow in cavities on the fronds of the fern and fix nitrogen from the atmosphere. The azolla can be used as a green manure in rice production to reduce the amount of manufactured nitrogen fertilizer used. Azolla technology has been long and widely used in Vietnam and China by rice farmers. IRRI helped to introduce azolla into the Philippines, and has also helped in the exchange of azolla germplasm among countries, including some azolla strains presently in use in Vietnam and China.

The best documented success of spreading azolla in S.E. Asia is in the Philippines. There IRRI, PCARRD and the Ministry of Agriculture had a cooperative project to test azolla in farmers' fields. It performed best in the irrigated areas of South Cotabato in Mindinao. The Ministry decided to publicize the value of azolla and distributed samples to a large number of farmers in 1980. By late 1981 it was being used on about 5000 ha of irrigated riceland in South Cotabato. A constraint to its adoption is the requirement for rather high levels of soil phosphorus and for relatively good water control and management, which means that prospects for its use in remote upland areas where fertilizer is most expensive are poor.

A small sample of the South Cotabato farmers was interviewed to determine the economic returns to azolla use in 1981 and 1982 (Kikuchi 1984). The major impact of azolla use was that farmers who incorporated azolla into their plots reduced their use of nitrogen fertilizer from about 40 to 25 kg/ha. There was no measurable change in yield. Some farmers also reported a decline in herbicide and hand weeding costs because azolla covers the surface of the water and supresses weeds. Evaluating these benefits at 1981 prices, the cost reduction ranged from $12 to 44 $/ha, more than 3 to 10 percent of the nonland cost of rice production. Thus, by 1981, those Philippine farmers had already saved between $60,000 and $220,000.

7.2.5 Crop intensification

The use of short-duration varieties and improved management practices has enabled certain regions to increase the intensity of cropping patterns. A good example is the case of Bangladesh wheat.

The national multiple cropping index increased from 1.45 to 1.54 in 1972/73, when semi-dwarf wheats were first introduced, to 1.54 in 1981-82 (Bangladesh Bureau of Statistics 1984). This coincided with the rapid adoption of semi-dwarf wheat varieties (Figure 7.1). The additional land planted to wheat resulted from increases in multiple cropping, not reductions from other crops. Between 1972/73 and 1981/82 the area of land single cropped in Bangladesh fell by 0.5 mil ha and the area double and triple cropped increased by 1.9 mil ha (Bangladesh Bureau of Statistics 1984). The area in other crops increased from 11.3 mil ha to 12.3 million ha, so there is no obvious indication that wheat substituted for other crops.

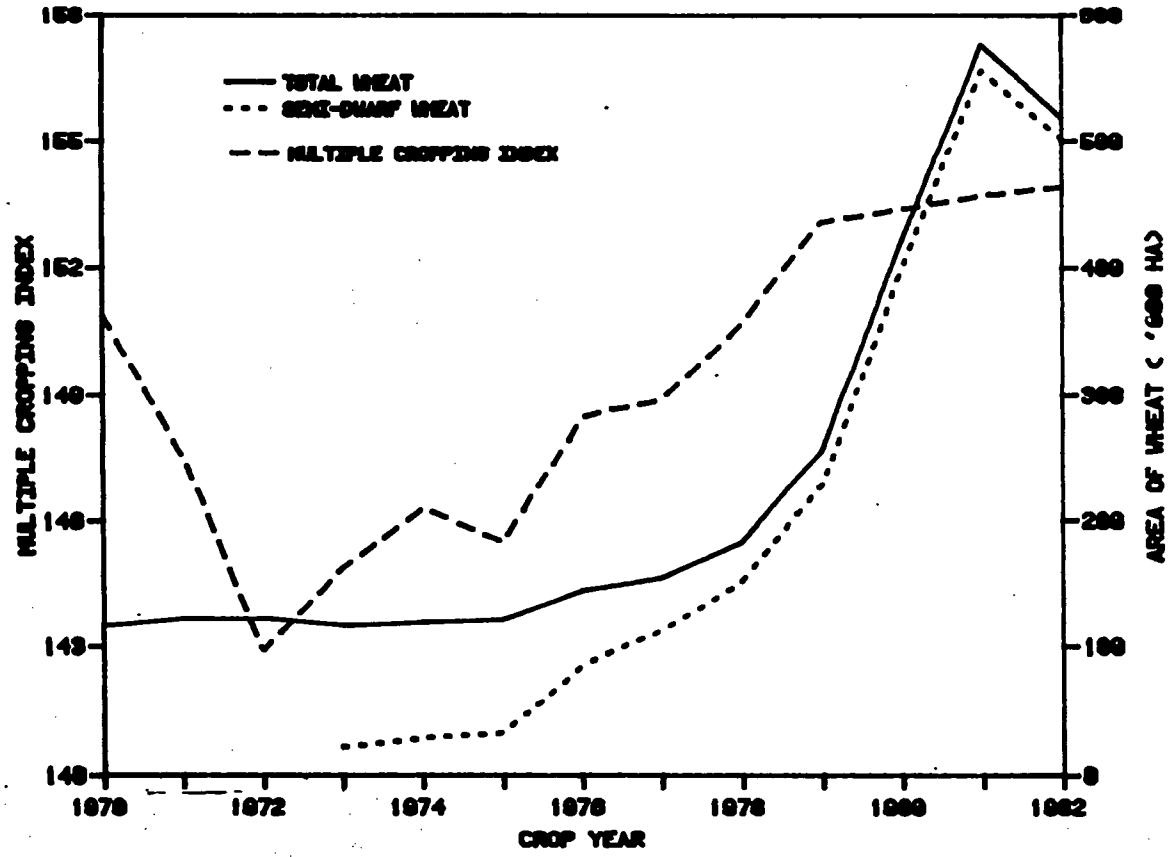
The increased food production from the added wheat land could be conservatively valued at $200m per year, with additional profits to farmers amounting to perhaps $40m per year.

IITA has developed many early maturing cowpea varieties. Some mature in only 60 days after planting. These varieties are an important key to intensified food production in rice-based cropping systems. Planted through rice stubble soon after the harvest of rice, the cowpeas grow on residual moisture as a catch-crop. They therefore permit two crops where only one was previously grown or three where two crops were grown before. This practice has already been adopted by a large number of small-scale rice farmers in the "fadamas" or wet valleys along the Kaduna and Niger rivers. This system is also being jointly tested in Asia by IITA and IRRI.

While there has been no worldwide survey to find the amount of intensification that has been due to varieties or management techniques developed by collaborative research between national research systems and the

Figure 7.1

MULTIPLE CROPPING INDEX, TOTAL WHEAT AREA AND AREA OF SEMI-DWARF WHEAT IN BANGLADESH, 1969-70 TO 1981-82



centers, there are a number of specific examples that can be cited. A major problem is to separate the intensification due to research from intensification due to population pressure or irrigation projects which had nothing to do with either international or national research. In the case of Bangladesh, irrigation for wheat increased, but over 60 percent of the new wheat area is grown without irrigation, on residual moisture and with sparse winter rains.

Several village level studies have linked new technology from farming systems research with intensification. Some examples are reported in Table 7.2. In a Javanese village "the introduction of double-cropping was facilitated by the diffusion of modern semi-dwarf varieties which mature early and are nonphoto-sensitive" (Hayami and Kikuchi 1982). Early maturing improved rice varieties in Nepal increased rice yields, allowed more optimal planting dates for the following crops(s) and made growing more crops per year possible (Van der Veen 1983). The deep Vertisol technology discussed in section 7.2.3 is a crop intensification strategy for the semi-arid tropics (Walker 1983).

Another fairly well documented case occurred in Iloilo province in the Philippines. The key techniques in this case were short-duration rice varieties, methods for direct seeding of the first rice crop and weed control using herbicides. These techniques allowed time for either two rice crops, or a rice crop and an upland crop to be grown where one rice crop had been the previous norm. The government Kabsaka project which is using these elements developed at IRRI had spread to 36,000 ha in Iloilo by 1984. Intensive research in several villages in the province found the system resulted in an increase in cropping intensity from 1.2 to 1.8, an increase in total rice

Table 7.2 Changes in cropping intensity associated with collaborative research

Location	Period	Multiple-cropping Index Start	Multiple-cropping Index Finish
	Rice Based Systems		
Bangladesh, National	1972/73 to 1981/82	1.45	1.54
North Subang village Java, Indonesia	1968/71 to 1978/79	1.50	2.00
Iloilo Outreach site Philippines	1974/75 to 1978/79	1.18	1.84
Dhobini village Nepal	1977/78 to 1980/81	1.59	1.68
	Semi-arid Tropics		
Taddanpally Watershed AP, India	1980/81 to 1982/83	1.06	1.39
Sultanpur Watershed AP, India	1981/82 to 1982/83	1.06	1.72
Farhatabad village Karnataka, India	1981/82 to 1982/83	1.29	1.67

yield of about 0.5 t/ha, and an increased income of between $140/ha and $500/ha; province-wide production increased by 18,000 t of rice and income by $5-18M.

7.2.6 Cassava drying technology

CIAT has been involved with Colombian farmers in the development of techniques for drying cassava so that it can be sold as cassava chips for animal feed. The process consists of chipping the cassava roots in a powered chipper modified from a machine used for the same purpose in Thailand, and spreading the cassava chips on a flat concrete surface to dry under the sun for 2-3 days. The chips must be turned six or eight times each day to ensure uniform drying; drying is terminated when the moisture content of the chips is about 14 percent.

This process was introduced to the north coast of Colombia in 1980. This area is dry and infertile, and only cassava and a few other crops grow well. CIAT worked with a small producers' cooperative which was also receiving assistance from an integrated rural development program. By 1982, the cooperative had expanded and was operating on a semi-commercial basis. It sold all 39 tons produced to a feed company in Cartenga. By 1983, this plant had expanded output to 270 tons and in 1984 there were seven plants in operation with 20 more being established in N.E. Brazil, Mexico and Panama.

7.2.7 Cassava management

The Cubans have extensively adopted the "Colombian" system of cassava production by adapting CIAT recommendations, in some cases using research methods learned at CIAT, to Cuban conditions. They selected the best local varieties and then taught agronomists from the state agricultural enterprises

the new management methods. These included: (a) good soil preparation with construction of ridges taller than those used for sugarcane; (b) selection and treatment of 30 cm stakes from the basal part of mature plants, to reduce the problem of cassava bacterial blight; (c) planting vertically on top of the ridges; (d) timely weed control; and (e) reduced irrigation. Before the training, Cuban farmers had planted short stakes horizontally on the bottom of small ridges and irrigated heavily.

Cuban cassava production increased from 24 kt in 1974-76 to 330 kt in 1981-83 (FAO). CIAT estimated that 10,000 of the 50,000 total ha used the "Colombian" system. Evidence from the Cuban Minister of Agriculture is that yields increased from 7 to 20 t/ha on the state farms. Assuming that the area using the new methods included at least 10,000 ha of state farm lands, the increase in output is 130 kt of cassava valued at about $4M.

7.2.8 IRRI mechanical innovations

The range of center-related agricultural machines is surveyed in chapter 18, and those associated with IRRI in particular in section 18.4. They are mentioned here in the context of output effects realized from research findings other than related to plant breeding because they have doubtless had some significant effects in reducing costs and thus encouraging increases of output albeit with some displacement of labor, as reviewed in the more general discussion of mechanization of chapter 8.

Consider initially the case of improved rice threshers. Farmers adopt those variously: (a) to reduce the cost of threshing, (b) to save turnaround time so that subsequent crops can be planted earlier and (c) to reduce crop losses in threshing. The empirical evidence indicates that, in the

Philippines where the threshers are replacing hand beating or foot treading, there is virtually no reduction in the cost of threshing a ton of rice but substantial reductions in producers' losses in threshing. In Thailand, the previous method was animal or tractor treading. Studies in Thailand show there are slightly greater grain losses with the IRRI threshers but there was a substantial reduction in the cost of threshing. There is no evidence that mechanical threshing reduces turnaround time.

Whatever the source of economic gains, the monetary net benefits of using the threshers are considerable and range from about $30-80/yr for portable machines in the Philippines and Thailand to $400/yr for large machines in the Philippines.

7.2.9 Land clearing and management technology

One way to increase food production in the humid and subhumid tropics is to bring forest land under cultivation. But such new land development projects must be carefully planned and executed, otherwise lush tropical forests turn into barren lands in a relatively short period. IITA's farming systems scientists have, for over ten years, investigated various methods of clearing tropical forests and the effects of these methods on subsequent crop production. These studies have led to the development of a package of recommendations for land clearing and soil management.

Land clearing should be done in a way that minimizes soil disturbance; thus, wherever possible heavy machinery should not be used. A mechanized clearing operation should not remove the litter, roots or stumps nor scrape off the top soil, should not compact the subsoil nor drag trees or stumps over long distances. Following clearing, residue mulch should be maintained on the

soil surface and mechanical tillage should be kept to an absolute minimum, for soil distrubance and its exposure to intense tropical rains are the causes of soil erosion. IITA has promoted this technology through publications, conferences and workshops.

This land clearing and management technology has been adopted by the Sumatra-Indonesia Transmigration Schemes, the World Bank-funded agricultural development projects (ADPs) in Nigeria, Ivory Coast, and Cameroon, land development projects in N. Thailand and in Yurimaguas, Peru.

7.2.10 Plant protection

The major plant protection technology advanced by the centers has been the production of pest-resistant varieties or making pest-resistant germplasm available to national systems. In addition, the centers have developed other means of reducing the ravages of pests and diseases through biological control and integrated pest management.

Centers have screened insecticides, herbicides and fungicides for their effectiveness against pests. This screening is used by governments and farmers to help to determine which chemicals should be used. The testing has undoubtedly saved money by providing governments with information that has helped them to avoid inappropriate chemicals. IRRI research on the role of insecticides in the resurgence of brown planthopper led the Philippine government to take methyl parathion off the list of approved pesticides that were supplied at subsidized rates.

Center research has also hastened the acceptance of certain weed-control measures. Thiobencarb, a herbicide tested by IRRI, is now used in 55 rice-

growing countries. Butachlor, also tested by IRRI, is now marketed in 22 countries. Informal discussions with officials from chemical companies revealed the opinion that IRRI tests had accelerated the initial acceptance and spread of new herbicides by several years.

IITA's biological control project on cassava green spider mite and cassava mealybug is a major biological control effort. Cassava green spider mites were first reported in Uganda in 1971, and the cassava mealybug was identified by an IITA research team in Zaire in 1973. It is assumed that these pests were introduced accidentally from Latin America. Their spread has been rapid and they are now found in over 60 percent of the cassava growing areas of Africa, in a wide belt of Mozambique in the east through Zaire and the Central African Republic, across the coastal regions of W. Africa to Senegal and Guinea Bissau. It has been estimated that these two pests cause economic losses of nearly $2 billion yearly in Africa.

IITA has addressed these pests in two ways. First, there is the conventional breeding program in which sources of resistance to the two pests have been identified and are being incorporated into cassava breeding lines. Also, attempts are directed towards using both cultivated and other Manihot species in the development of higher levels of resistance.

The second approach, biological control, introduces host-specific natural enemies from the pests' area of origin in S. America as a means of effectively reducing pest populations to the tolerable levels that exist on that continent. CIAT collaborates in the search for natural enemies in S. America.

From November 1981 to the end of 1984, approximately 50,000 of the cassava mealybug's natural enemy Epidinocarsis (Aposnagyrus) Lopezi were released in 10 African countries: Congo, Gambia, Ghana, Guinea-Bissau, Nigeria, Rwanda, Senegal, Togo, Zaire, and Zambia. The establishment of E. Lopezi - a wasp that parasitizes the mealybug - has been recorded in eight of the countries. A natural enemy is considered established when it has survived a full rainy season, the period of low mealybug population, and has been located again 12 months after release.

A significant reduction in the number of cassava mealybugs to below the injury level has been observed in every zone colonized by E. Lopezi. In those zones, the mealybug now reaches peak population densities of only 10 to 20 per terminal cassava shoot and often less than this number, compared with a peak population of more than 1,500 per shoot before the introduction of the wasp.

New attempts are being made to find additional effective natural enemy species. A complex of species would be more desirable to assure a permanent and reliable suppression of the mealybug.

7.3 Coda

* It is more difficult to develop estimates of the impact of management technology than of germplasm technology and the problems of attribution are more complex.

* Programs to improve potato seed are being carried out in a number of CIP-

national research system collaborative programs. The technique of diffused light storage reduces sprout elongation, increases sprout numbers, reduces total storage losses, and allows a longer period of storage. This system is now being used extensively by farmers in Peru, Colombia, the Philippines, Sri Lanka and elsewhere.

* ICRISAT has developed a package of improved technological options for increasing output on deep Vertisols in the wetter areas of semi-arid India. This system is being used on about 4000 ha in on-farm tests by national program researchers and extension workers in the states of Karnataka, Andhra Pradesh, Mahrashtra and Madhya Pradesh.

* IRRI has helped to introduce the biological nitrogen fixing system using azolla into the Philippines, and has helped in the exchange of azolla germplasm among countries. One study in the Philippines found that farmers who incorporated azolla into their plots reduced their use of nitrogen fertilizer from 42 to 24 kg/ha, without reducing yields.

* The use of short duration varieties and improved management practices has enabled certain regions to increase the intensity of cropping patterns. The classic case is Bangladesh wheat affecting 0.5 million hectares; the deep Vertisol technology is also a crop intensification strategy.

* CIAT has assisted Colombians in the development of techniques for drying cassava so that it can be sold as cassava chips for animal feed. By 1983, there were seven plants in operation in Colombia, with 20 more being established in northeast Brazil, Mexico and Panama.

* Cuban farmers have extensively adopted the "Colombian" system of cassava production which consists of adapting CIAT recommendations.

* The monetary net benefits of using the IRRI threshers range from about $30--80/yr for portable machines in the Philippines and Thailand to $400/yr for large machines in the Philippines.

* The major plant protection technology advanced by the centers has been the production of pest resistant varieties or making pest-resistant germplasm available to national systems.

* IITA has introduced biological control of major cassava pests to severely affected producing areas in 10 African countries and significant reductions in pest population have been observed.

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8 DISTRIBUTIONAL AND NUTRITIONAL IMPACTS OF CENTER-RELATED VARIETIES

8.1 Introduction

In this chapter the influence of modern crop varieties 'in the large' on income distribution and nutritional status, especially among the most impoverished groups is addressed. Many new varieties can be associated more-or-less easily with crop improvement activities of the centers, but in this review no attempt is made to distinguish between the contribution of the individual centers and of the other key factors in the production of modern varieties. Much of the chapter is based on a study paper prepared by Michael Lipton with the assistance of Richard Longhurst (Lipton and Longhurst 1985).

8.2 How Modern Varieties of Food Staples Affect the Poor

After 20 years of experience with the modern varieties, the effects on the poor surely should be known. This chapter is intended to reassess the vast research literature on this topic in a way that may lead to the setting of a revised agenda for enquiry and action, by the centers and others, to improve the poverty-reducing impact of modern varieties.

The 20 years since the first introduction of modern varieties have been perceived by social scientists more or less in four quinquennia:

(a) In 1966-70, the "miracle seeds" were to solve the food consumption and production problems of rich and poor alike (e.g., Brown 1970).

(b) In 1971-75, the "green revolution" allegedly enriched the rich but impoverished the poor, thus threatening or promising to turn red (e.g., Frankel 1971, Borgstrom 1974).

(c) In 1976-80, consensus grew that modern varieties helped many of the poor (except farmers in neglected areas), but less than the rich. Small-scale farmers, though adopting late, attained good yields. Hired employment increased, but seldom wage-rates. Above all, as modern varieties increased food supply, they kept food prices to poor consumers down.

(d) In 1981-85, there are claims that modern varieties often raise poor people's levels of living faster than rich people's, even if the institutions of land tenure, rural credit, etc. are wrong. If poor farmers lose land, if rich farmers replace workers by threshers, modern varieties are largely guiltless (Barker and Herdt 1985, Hayami 1981).

Is it merely research fashions that are changing? Is the farm reality changing, as poor farmers catch up with the leaders in use of modern varieties? Or are the latest modern varieties themselves different from early ones,

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perhaps more "poor-friendly", as breeders aim more at drought and pest resistance (Herdt and Capule 1983) and at poor people's crops like sorghum?

Past scientific research has sought modern varieties helpful to the poor by using more labor, supplying cheap food energy, etc. Socio-economic research has documented these effects on the poor, which are real and good. But, in the total context, most of Africa is without modern varieties and is poorer than in 1970, and the incidence and severity of poverty in S. Asia are little changed despite modern varieties. Diagnosis of means to alleviate poverty in these situations increasingly needs to start from the reality of members of typical poor households who may well simultaneously be "small-scale farmers", "employees" and "off-farm food consumers".

A research agenda for social scientists concerned with development will probably move gradually from the economics of particular farm practices and adoption decisions of specified groups of farmers to the socio-economics of poor people's total positions. This might involve, for example, asking how and why the well-being of the poorest, say, fifth of the population in modern-variety areas, in other farm areas, and in cities, changes in the wake of modern varieties. Analogously, the agenda may move from analyzing, after the event, particular effects of modern varieties on particular groups of poor people, toward recognizing the overriding effect of resource ownership on income distribution, and the limited role that the design of new modern varieties and recommended practices can have in determining the welfare of the poor, aside from reducing the costs of food consumption. Some of these issues are returned to in section 8.4.5.

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8.3 Physical Features of Modern Varieties: Impact on the Poor

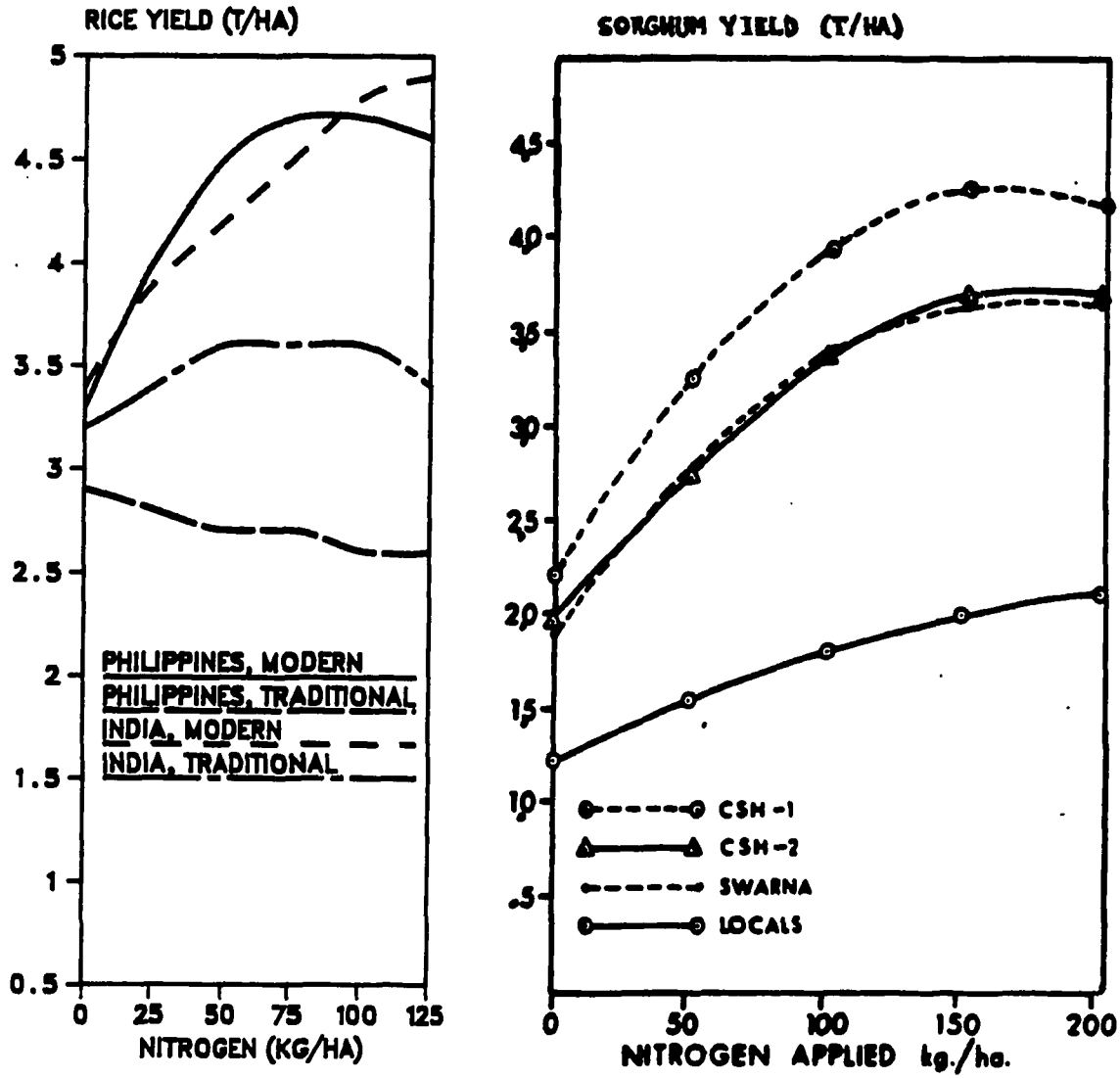
8.3.1 Soil nutrient response

Many critics claim that, if the poor cannot afford fertilizer, they lose by switching to modern varieties because these then yield less than traditional varieties. This claim is wrong. Modern varieties are indeed designed to yield much more at high levels of the macro soil nutrients, nitrogen, phosphorus and potassium (N, P, K, respectively) from all sources, e.g., by not lodging (dwarf and semi-dwarf modern varieties) or by hybrid vigor. But such design aims to convert NPK more efficiently into grain weight, and so most modern varieties outyield traditional varieties even with no fertilizer (IRRI 1975, pp.19-21, Kahlon 1974, p.5), especially as denser plantings then tend to mean fewer weeds. This is illustrated in Figure 8.1 for rice and sorghum. A number of experiments comparing modern with traditional rices and modern with traditional sorghums were compiled. The individual experiments as well as these averages show that modern varieties have both higher response to applied nitrogen, and higher yield at zero applied nitrogen. As newer modern varieties are bred to resist pests and diseases, their advantage over traditional varieties at zero fertilizer has increased (Byerlee and Harrington 1982), even under moisture stress (Barlow et al. 1983, Rao 1982). Still, there are worries for the poor.

First, modern varieties must get the extra nutrients, mainly N, P and K, needed for higher yields, from somewhere. At zero fertilization, this risks "soil mining" although many soils have sufficient available P and K to last for decades, even at high extraction rates. The centres and their partners should

FIGURE 8.1

YIELD RESPONSE OF RICE TO APPLIED NITROGEN ON 30 EXPERIMENTS IN THE PHILIPPINES AND 18 EXPERIMENTS IN INDIA (BARKER AND HERDT, 1985) AND YIELD RESPONSE OF SORGHUM TO APPLIED NITROGEN ON 25 EXPERIMENTS IN INDIA (SINGH, KRANTZ AND BAIRD, 1970)



perhaps look more beyond single-season fertilizer responses, and should design, for poor farmers, modern varieties and total nutrient policies to preserve long-run soil-food security. Second, a few aberrant modern varieties perform worse than traditional varieties with low or zero fertilizer. Third, the moderate yield advantages of most modern varieties at zero fertilization can be outweighed by price discounts below traditional varieties, and/or lower straw yield. Fourth, modern varieties bred for maximal grain/N ratios: (a) often reduce straw for fodder and thatching, (b) may require P or perhaps micronutrients such as zinc (Zn) purchases to achieve high yields, (c) may store badly due to thin husks, (d) may have higher seed costs, at least initially, or (e) may sometimes show larger yield loss under moisture stress. Handling these complexities requires purchases, information and risk-taking that may not be easy for poor, illiterate farmers. The result may be that they refrain from adopting when it may be in their own self interest to adopt. So, if these rather than laborers, or urban consumers are the main poverty group, center and other researchers need modern varieties, rotations and practices that are very soil-nutrient efficient, even under moisture stress, and even perhaps at some cost to yield potential. Poor people's crops especially (millets, sorghum, cassava), are often grown unfertilized on fragile soils, so efficiency of response to soil macro nutrients at low levels is critical.

8.3.2 Light response

Direct breeding for greater photosynthetic efficiency (via erect leaves) and reapportioning photosynthate between stem and grain was a major goal of the centers during the 1960s. Having achieved that for wheat and rice, it cannot

in the future be a major source of incremental gain as it was then. Indirectly, modern varieties with low photo-period sensitivity remain a major research goal. They thrive irrespective of the pattern of day-length, provided that total light, water and nutrients suffice. Often this permits double cropping and more even flows of food through the year (Bolton and Zandstra 1981); the poor gain most, since they can seldom save or borrow against lean seasons. But local specificity, not broad adaptability, is sometimes needed; for example, where plants should mature in the late rains to permit sun-drying, those who cannot afford mechanical drying methods may want high sensitivity to daylength in order to synchronize the flowering and maturity of the crop with the climatic environment (Beachell et al. 1972).

Many poor farmers, therefore, want high photo-period sensitivity at harvest time, but low sensitivity earlier. Center researchers, for example, may brilliantly seek out modern varieties and practices with criteria that the research community think are important. On photo-period sensitivity and other attributes, however, they may need to do more to be responsive to the "felt needs" and actual payoffs of their poorer clients before settling on criteria to guide their work.

8.3.3 Water response

Modern varieties have been criticized as raising yields only through use of more water, and as being more drought-prone than traditional varieties (Borgstrom 1974, Griffin 1975, p.205). Actually most modern varieties are bred for root structures that give better returns per unit of water, especially (but

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not only) where accompanied by higher nitrogen inputs (Borlaug 1972, Swaminathan 1974). But this very fact raises the payoff to farmers from getting more or timelier water -- perhaps at the expense of poor, weak, or tail-end users. Fortunately, modern rice varieties increasingly resist moisture stress better than traditional varieties, reflecting in part one of IRRI's main objectives since 1971 (IRRI 1972, p.85). Barley, millets and sorghums are similarly bred for vigorous root system. Hybrid sorghum has raised farmers' yields greatly in drought-prone areas of India (Rao 1982, pp.49-50). Wheat producers in Pakistan and Tunisia and rice producers in the Philippines and Bangladesh, without irrigation, have often adopted modern varieties mainly for drought resistance, not for good-season high yields (Barker 1972, Palmer 1972, Rochin 1973, Herdt and Capule 1983).

Most of the poorest people live in vast areas of unreliably rainfed rice, or of semi-arid crops. ICRISAT and ICARDA are concentrating their full attention on the latter such areas and the other centers are also now devoting substantial resources to rainfed agriculture, but most of these areas remain in traditional varieties. Why? (a) The politics of non-farmer controlled irrigation leave many farmers with inadequate, untimely water, so that the gains from switching to modern varieties are small. (b) Some research stations, such as IRRI headquarters, are located in well-watered regions and thus perhaps ill-equipped readily to analyze moisture stress, despite major outlays and field studies. (c) For semi-arid crops in Africa (and in Asia in winter) and for upland rice, the centers have not yet radically improved water use efficiency: their biological approaches (perhaps modified towards robust

intermediate-yielding varieties like H4 and C4-63 rice) may need to be integrated further with ecological engineering to, say, reduce evaporation, seepage and run-off, before farmers can gain the needed benefits. ICARDA's findings of improved water-use efficiency and earlier maturity of barley under phosphorus application offer scope for improvement in its mandate areas, especially if some governments' restrictions on use of P are lifted.

More research in water-insecure areas (and less on irrigated crops) means more income for some of the world's poorest farmers but may mean lower total returns, to research investment, and thus less, or costlier, food for the poorest consumers (Brass 1984). This apparent dilemma can be resolved only by major improvements to the water security of unirrigated farmland. These have become less fashionable with international donors and national governments due to the failure of irrigation "white elephants", and attempts to transform farmers' water use systems (e.g., by advising early planting) without understanding their constraints. Modern varieties linked to selective, farmer-controlled micro-irrigation (or micro-drainage) may be the only route to affordable, efficient increases in water-grain conversion rates in dry (or flood-prone) areas.

8.3.4 Stability against diseases, pests and weeds

The critics' claims of greater susceptibility (Griffin 1975, p.205, Palmer 1972, p.23, Whitcombe 1973, p.199), if true, would hit hardest at the poorest, who lack information and, in time of need, lack pesticides too. Some early modern varieties such as TN-1 and IR8 were indeed "insect pest museums" but

later ones possessed better resistance; IR20 rice lasted 10 years, Sonalika wheat 20. Currently, yield increases are bought mainly by raising robustness, not by sacrificing it to yield potential. The centers have also helped national breeders to respond quickly, e.g., to the successive brown plant hopper biotypes which emerged in Indonesia.

The centers' work seemingly has, however, understressed one of poor farmers' most damaging pest problems. Weed research seemingly: receives few resources (relative to weed damage); concentrates them on testing commercial weedicides (perhaps tending to displace poor workers rather than raising yields) (e.g., CIMMYT 1983, pp.89-91); and sometimes is rather unspecific about how to help in fighting which weeds, in which crop (let alone which farm system) when, where and with what costs and benefits. Weeds can be very damaging in dry areas where they compete for scarce soil moisture (mainly women's labor for control, and accordingly are receiving some attention at ICARDA. Rats and bird pests also seem grossly neglected by the centers, in view of the relative damage they do in technology-poor Africa (Jones 1982, p.720, ICRISAT 1983, pp. 4, 83, IRRI 1983).

The narrow genetic base of modern varieties is a danger being tackled by the centers (chapter 12), and fears that the poor are threatened have been exaggerated (Mooney 1979). The centers have unprecedented, freely accessible germplasm collections, and have used wild races when traditional varieties, too, prove vulnerable (cf. the use of O.sativa genes against grassy stunt in rice). Breeding for yield is seldom anti-poor and may be pro-poor. Dense

modern-variety stands hinder weed growth. Fertilizers can also help but may increase resistance to tungro in rice and alternaria in wheat. Irrigation should not increase disease (Saari and Wilcoxson 1974, p.50) but modern-variety induced double-cropping, especially of the same crop, gives pests year-round homes (IRRI 1973, p.74). Generally, modern-variety research has enormously reduced disease and pest risks faced by growers. This helps the poor most. Their risks remain great, however, if with reduced genetic diversity, national research systems cannot respond quickly with resistant materials (as Indonesia with the assistance of IRRI did when IR36 proved vulnerable to biotype 3 of the brown plant hopper).

Modern varieties enhance yields via short stalks, erect leaves and dense roots. These, respectively, improve efficiency of use of nutrients, light and water, and therefore the capacity to tolerate shortfalls or mis-timing of them. The better modern varieties are also being made more tolerant of pest and disease attack. The social and economic systems into which they are introduced, however, often thwart, or even reverse, the pro-poor effects of all this.

8.4 Modern Varieties and Distribution of Benefits among Farmers

Initial research on the relationship between farm size and adoption showed that large-scale farmers adopted new varieties sooner than small-scale farmers. This has led to the wide misperception that small-scale farmers are non-adopters, but the great mass of evidence shows that, where modern

varieties are suited to the edapho-climatic conditions, they have been adopted by roughly the same proportion of farmers in all farm size groups. This is illustrated in Figure 8.2 for several sets of data on Asian rice producers.

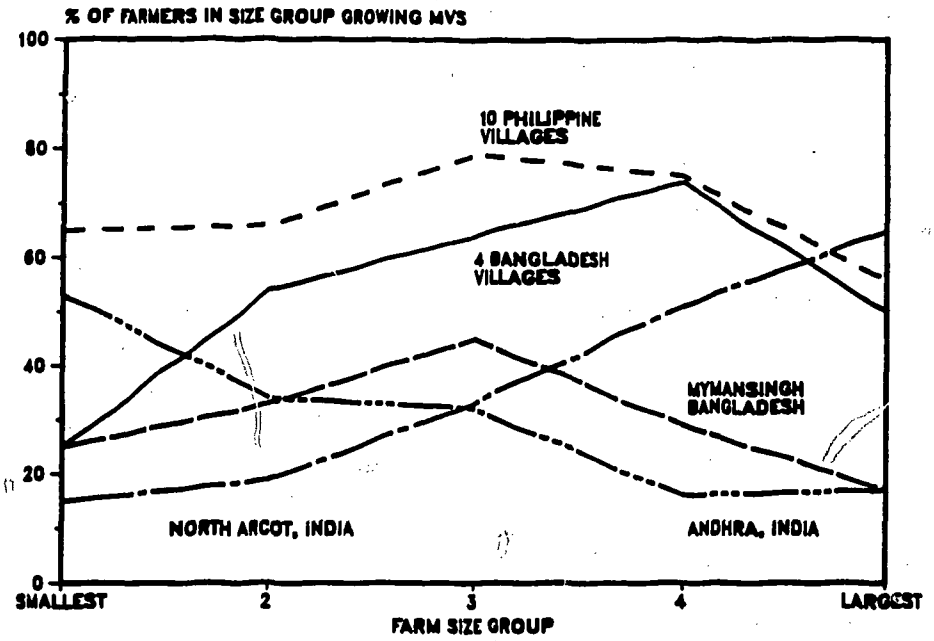
A broadly-based examination of a significant Asian example of the relationship between farm size and use of modern varieties is possible from data for the mid-1970s collected in a nationwide study by the National Council of Applied Economic Research of India. Data from three representative states are plotted in Figure 8.3 The percentage of crop area planted to modern varieties was computed for each of five categories of farm size, namely: <1, 1-2, 2-4, 4-10, >10 ha).

In some states, such as Madhya Pradesh, most of the land was planted to traditional varieties while in others, such as Haryana, most was planted to modern varieties. No positive association is apparent between farm size and percentage of area in modern varieties and, in cases such as Uttar Pradesh there is, if anything, an inverse relationship. It is also revealed that, while the modern varieties are largely irrigated, there were also signficant areas of traditional varieties that were irrigated at the time the study was conducted.

8.4.1 Adoption, farm size, tenure and risk

Research on relationships between size, adoption and yield does disclose something about how modern varieties affect the poor -- although perhaps more about the prospects in particular rural societies of coherence and stability,

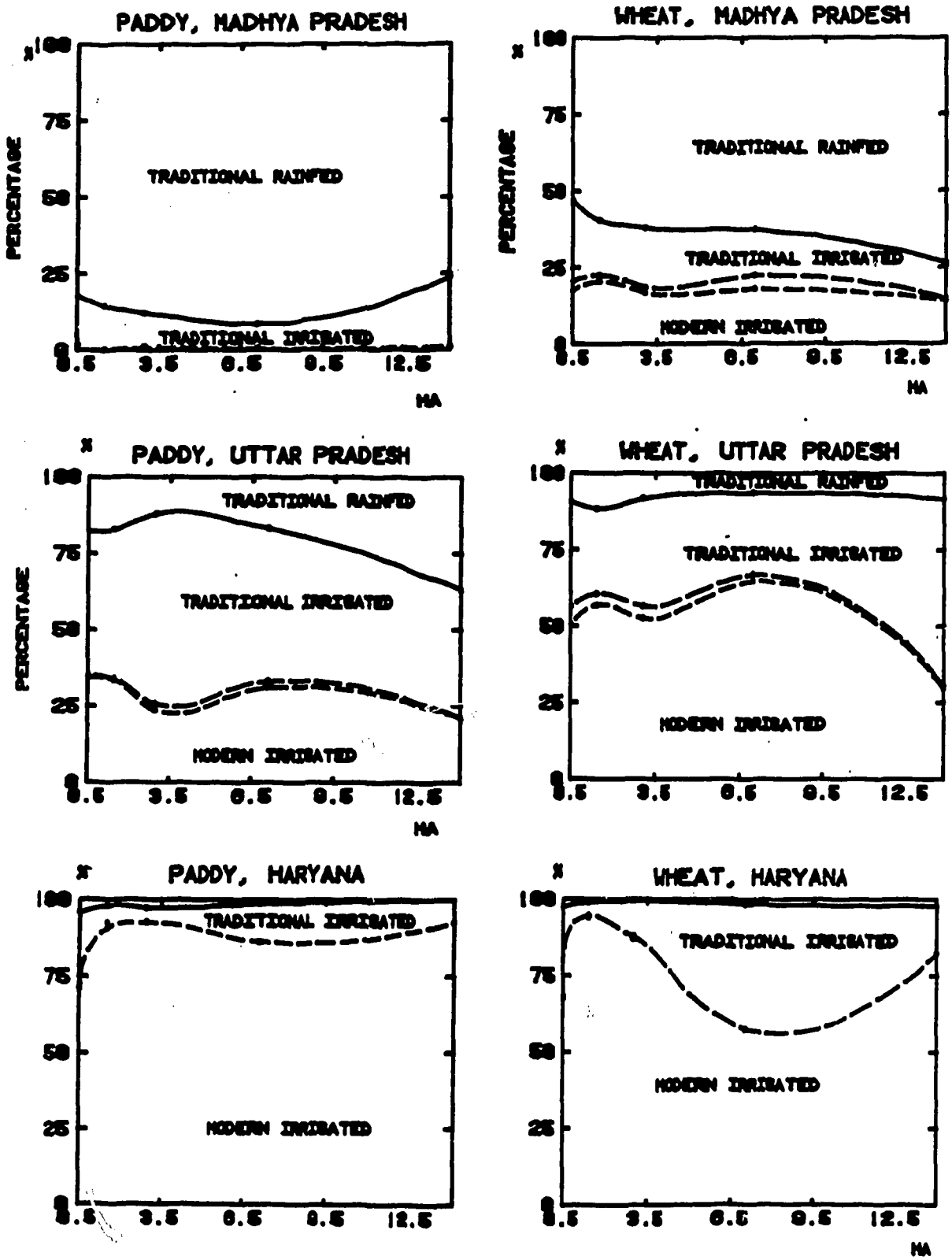
FIGURE 8.2



SOURCE: HERDT AND CAPULE 1983 AND MUTHIAH 1971

FIGURE 8.3

PERCENTAGE OF LAND IN FARMS OF DIFFERENT SIZE GROUPS PLANTED TO MODERN AND TRADITIONAL RICE AND WHEAT VARIETIES IN SELECTED STATES OF INDIA, 1975-76.



insofar as these depend on the spread of scientific farming beyond large-scale farmers. Early studies clearly showed that large-scale farmers were indeed adopting modern varieties relatively quickly (Lockwood et al. 1971, Schluter 1971, Herdt and Capule 1983, p.3). Later work showed that small-scale farmers were catching up (Dasgupta 1977, pp.227-8, Byerlee and Harrington 1982, p.3, Barker and Herdt 1984, pp.24-33), often leaving the bigger ones, however, with "innovators' rents". This catch-up is not happening everywhere (Herdt and Garcia 1982) and is by no means automatic.

Unfortunately, not all modern varieties are smallholder-friendly and smallholders, although adopting readily in the right circumstances, are more often located in the wrong ones (no irrigation, bad topography, no extension) than richer farmers (Cutie 1975, Colmenares 1975). In Mexico, poor ejidatarios (communal farmers) more readily than small private farmers could restructure their assets so as to benefit from modern varieties (Burke 1979). Owner-farmers do not adopt more than tenants unless as often happens, tenants get more costly credit per hectare.

Because they avoid risk until they have seen their wealthier neighbors succeed with modern varieties small-scale farmers may adopt later; or because they cannot get scarce inputs at first they may delay adoption. Credit appears more constraining in irrigated areas, risk elsewhere (Schluter 1974, Anderson and Hamal 1983). Risk may deter adoption only where the techology has fixed cost (Feder and O'Mara 1981, pp.60-1). This theory is supported by studies suggesting that, where smallholders adopt later, they sow a bigger proportion

of land to modern varieties than do larger scale farmers so as not to spread their fixed costs over too small an area (Dasgupta 1977, pp.229-32, Asaduzzaman 1980, Herdt and Garcia 1982).

8.4.2 Inputs and incentives to support modern varieties

Are modern varieties normally, or causally, linked with labor-displacing inputs, which favor bigger farms with more savings and less family labor per hectare? Rice modern varieties indeed were strongly linked to herbicides, tractors and threshers in tightly-scheduled double-cropping areas such as the Philippines, Malaysia, W. Java (Barker and Herdt 1978, pp.85, 87, cf. Gibbons et al. n.d., p.221, Lingard and Baygo 1983). In some of these locations the development of short duration varieties made double cropping possible. Even shorter duration varieties, presumably with some sacrifice in yields, could help to spare smaller farms and landless laborers from the effects of threshers and tractors.

Do modern varieties generally yield better for big farms because they effectively utilize more inputs? Richer farmers are better able to afford timely fertilizers and to seize timely tubewell water (Dasgupta 1977, pp.91-2, Smith et al. 1983). But can selected modern varieties help small farmers to substitute manure, or labor-intensive methods of applying water or fertilizer for more input purchases? In the longer term, modern varieties tend to receive similarly high levels of inputs on small and large farms. But institutions allocating water, fertilizers, or credit tend to be biased toward large farms, especially those owned by men. If the biases cannot be corrected and if the

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research system is to be friendly to the poor, technologies should be selected to help smaller scale operators to overcome such biases.

Later adopters, usually the poor, often receive output prices reduced by the effects on supply of the early adoption by their better-off neighbors. Richer farmers may also get better prices than the poor via scale-economies in marketing or timelier sales, and modern varieties seem to increase these advantages (Swenson 1973, pp.77-8. 113, 1976, p.3). Resource-poor farmers may, however, avoid such disadvantage by eating most of their additional modern-variety output (Cordova et al. 1981, Deuster 1982).

8.4.3 Farm size, yield, efficiency and modern varieties

Small-scale farmers ultimately adopt as much and as intensively as others. Having more family labor per hectare, they usually get higher yields. A few data suggest that modern varieties reverse the traditional "inverse relationship" of smaller farms to higher yields (Roy 1981, Bhalla and Chandha 1983, pp.62-73). Small farms are, however, usually protected in their yield advantage by several factors. After full adoption, they get the benefit of greater cropping intensity and crop value. At an earlier stage, slightly lower yields per season on smaller farms, with lower purchased inputs per hectare, may be privately and socially efficient, but as they progress fully to modern varieties, the traditional "inverse relationship" reappears (Chattopadhyay and Rudra 1976, ps A-109, A-117, Byerlee and Harrington 1982, p.3).

In Bangladesh, about 12 percent of farmers 1 ha and below are growing semi-dwarf rice varieties while a slightly smaller proportion of farmers with over 1 ha is growing them (Figure 8.4). The highest proportions of fertilizer users are in the three smallest farm size groups, and the use of irrigation closely parallels the adoption of semi-dwarf rices. Thus, even in Bangladesh, which ranks second to Chad in the World Bank's poverty list, small-scale farmers are alert to the possibilities offered by new technology.

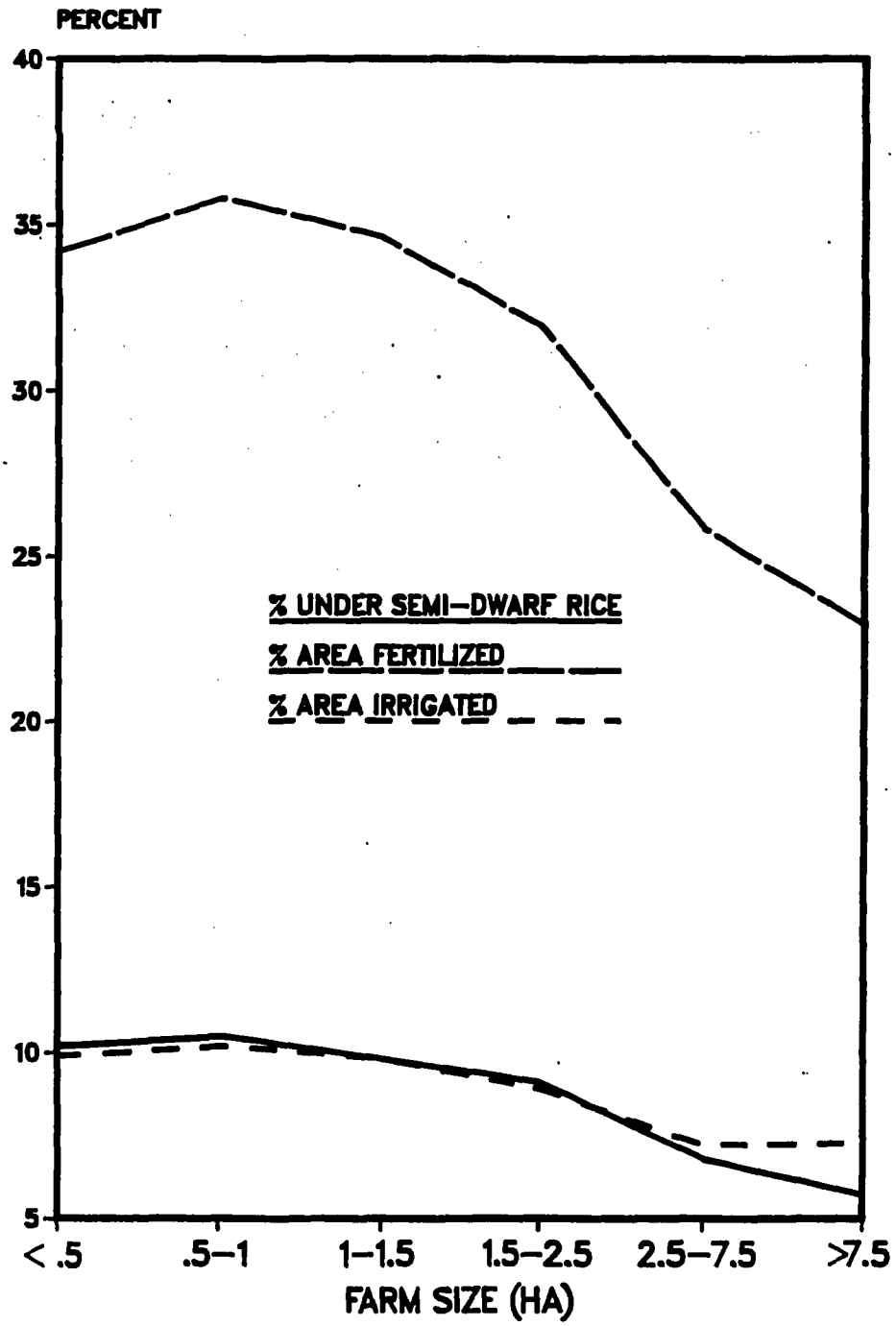
Small farms with more family labor per hectare should do best out of modern varieties. Those with little access to timely inputs probably do badly and thus the centers should continue to investigate how modern varieties might be more robust against their failure.

Producers on small farms could lose land via eviction or foreclosures. There are some notorious cases, e.g., Chilalo, Ethiopia (Cohen 1975, pp.348-9). Mini-holdings in India, however, have increased their share of farms and areas (Vyas 1979). There is no general link of modern-variety adoption or yield to largeness of farm or owner-occupancy. Modern varieties cannot be blamed for machinery subsidies or land reform evasion, although managers of systems who do gain from such abuses have also been quick to exploit the gains from modern varieties (see also section 8.7).

Despite earlier gloomy assessments, most recent work concurs that, if most poor people in modern-variety areas are smallholders and keep their land, modern varieties raise their average net income (Barker and Herdt 1981,

FIGURE 8.4

RELATIONSHIP BETWEEN FARM SIZE AND USE OF MODERN AGRICULTURAL TECHNOLOGIES IN BANGLADESH (BANGLADESH BUREAU OF STATISTICS, 1980)



Pinstrup-Anderson and Hazell 1984) and consumption (see Feature: Rice and North Arcot). But do they make it less stable? India's sorghum, millet, and all-foodgrain yearly output variability has risen in the post-modern-variety period (e.g., Hazell 1982, 1984, Walker 1984, and chapter 6). But output variability, especially variance but also even coefficient of variation, is a bad measure of riskiness. It has been raised nationally, mainly because yields and modern-variety areas vary together, not because individual farm outputs vary more (let alone are worse in bad years than for traditional varieties); the reverse is the case. By seeking greater genetic diversity and otherwise, the centers will continue to reduce individual disaster risk.

Feature: Modern Rice and North Arcot, India

North Arcot, an important rice growing district in S. India, has benefited substantially from improved rice varieties. Prior to the release of modern varieties, average yields were growing at an annual rate of about 1.4 percent. With the release of modern varieties in 1966/67, this growth rate accelerated nearly 4 percent per annum, providing an accumulated yield increase of over 1 t/ha by the early 1980s.

The first modern varieties released in North Arcot were Taichung Native 1 (from Taiwan) and ADT27 (developed locally). Beginning in the early 1970s, these varieties were rapidly replaced by IR8 and IR5. Of the 38 paddy varieties released in the area since 1975, 23 had IRRI germplasm in their parentage. The share of the paddy area planted to modern varieties increased from 20 percent in 1970/71 to 90 percent in 1981/82.

Modern varieties were the predominant source of growth in rice yields, but also important were sizable increases in the use of fertilizers, pesticides and irrigation water. The latter was achieved through increased investments in wells and mechanical pumping equipment.

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Total rice production has increased faster than yields because of a concurrent but modest increase in the gross cropped area. This is attributable to a combination of increased irrigation and the shorter growing period requirements of the modern varieties. In a sample of villages, the cropping intensity (ratio of gross to net paddy area) increased from 1.75 to 2.06 between 1973/74 and 1982/83.

These changes in rice production had widespread ramifications on the region's farm and non-farm economy, which can be analyzed using detailed socio-economic surveys conducted in 1973/74 (by Cambridge and Madras Universities) and in 1982/83 and 1983/84 (by IFPRI and the Tamil Nadu Agricultural University). A useful aspect of these data sets is that the samples of households were drawn from the same representative villages.

The average household in the sample villages more than doubled the real value of its consumption of food and consumer goods and services between 1973/77 and 1983/84. Further, this gain seems to have been shared by different types of households in rough proportion to the value of their total consumption in 1973/74 (Table F8.1)

These increases in the value of per capita consumption were accompanied by a shift towards more varied diets, with all household types increasing the share of pulses, livestock and horticultural products consumed relative to cereals. There were also significant increases in the proportion of household

Table F8.1 Comparison of the mean value of total consumption by different household groups in North Arcot, (constant 1973/74 prices)

Household Type	1973/74 All Villages Rs.	1973/74 All Villages Index	1973/74 Poor Villages Rs.	1973/74 Poor Villages Index	1982/83[a] All Villages Rs.	1982/83[a] All Villages Index	1982/83[a] Poor Villages Rs.	1982/83[a] Poor Villages Index	1983/84 Poor Villages[b] Rs.	1983/84 Poor Villages[b] Index
Small Farms[c]	1369 (110)	137	1142 (79)	113	1823 (107)	151	1635 (183)	131	2890 (136)	113
Large Farms[c]	2273 (242)	228	2346 (225)	233	3604 (237)	298	3483 (324)	280	5752 (694)	225
Paddy Farms	1962 (136)	196	1559 (138)	155	2822 (158)	233	2804 (245)	225	4418 (255)	173
Non-Paddy Farms	1458 (352)	146	1184 (369)	117	2215 (409)	183	1949 (593)	157	3329 (561)	130
Non-Agricultural Workers	1413 (101)	142	1162 (206)	115	1727 (294)	143	1114 (241)	89	2190 (215)	86
Agricultural Workers	998 (53)	100	1008 (67)	100	1209 (55)	100	1244 (101)	100	2553 (96)	100

Notes: Figures in parentheses are standard errors of estimates for the means. The index numbers reported are within year indexes of inequality using the total consumption of agricultural workers as the base.

a Drought year.
b Only poor villages were samples in 1983/84.
c Small farms operate 1 ha or less; large farms operate more than 1 ha.

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expenditure allocated to durables, medical care, transport, entertainment, house improvements, and religious and social events. The data did not include information on intra-household allocations so effects on the basis of gender and age, for example, cannot be differentiated.

When compared to the earlier rice varieties, the modern varieties use a little more labor per hectare but less labor per unit of paddy (Table F8.2).

However, the labor requirements for rice production have declined for all varieties since 1973/74 because of the increased mechanization of irrigation pumping and paddy threshing. Mechanization of land preparation is still not widespread in North Arcot.

Total employment in paddy farming increased slightly between 1973/74 and 1983/84. The average farm increased its total labor use in paddy from 88 days to 94 days of male labor and from 70 days to 83 days of female labor. Of these amounts, about one-third of the male labor is hired and two-thirds of the female labor is hired. There has been very little change since 1973/74 in the composition of labor use.

Agricultural wages vary by operation, gender and village, but there has been a general pattern of increase since 1973/74. The average daily wage for plowing (which is performed by men) in the sample villages increased from Rs. 2.23 in 1973/74 (Rs. 4.11 in 1982/83 prices) to Rs. 5.10 in 1982/83 - a real increase of 24 percent. Similarly, the average daily wage for transplanting

Table F8.2--Labor use in paddy production, North Arcot

	100 hrs/ha season	Hours/ 100 kg
Pre-modern varieties		
1972/73	19	89
1982/83	17	57
Modern varieties		
1972/73	20	64
1982/83	18	50

(performed by females) increased from Rs. 1.17 in 1973/74 (Rs. 2.16 in 1982/83 prices) to Rs.2.45 in 1982/83 - a real increase of 13 percent. During the same period, in-kind daily wages for harvesting (performed by female workers) increased by 11 percent and in-kind daily wages for threshing performed by male workers increased by 21 percent.

Initial estimates also show strong growth linkage effects to nonagricultural employment in the local towns. The total number of fulltime workers in the region increased by 30 percent between 1971 and 1981. Of this increase, about one-third of the jobs were created in non-agricultural activities. Ignoring other less important sources of growth, each 1 percent increase in the value of agricultural output was associated with 0.6 percent increase in agricultural employment, and a 0.9 percent increase in non-farm employment.

END Feature

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8.4.4 The real poverty problem: where modern varieties are not

Focus on small-scale farmers in modern-variety areas may have distracted attention from areas that have not much used modern varieties. Yet observers concur that such neglected areas have done badly (Ruttan 1977, p.18, Barker and Herdt 1984, p. 48). Poor wheat farmers and their employees in Madhya Pradesh, selling wheat to buy inferior coarse grains, lose absolutely when Punjab's burgeoning wheat output depresses prices. In non modern-variety areas with poor soils, initial poverty tends to be worse, and less unequal (Dasgupta 1977a), so that the chance of fairly shared gains would be better, if modern varieties do eventually take off.

There are exceptions. In Taiwan, all zones grow mainly irrigated rice, so all gained from modern varieties. In Pakistan, rainfed zones gained too from modern-variety wheats and regional inequality fell (Rochin 1973, Chaudhry 1982). But usually the poorest, less irrigated zones (Pacific S.W. Mexico, the E. Indian rice zone, Mindanao) have lost as the modern foodgrain varieties pushed leader zones further ahead (Tuckman 1976, Brass 1984). Non-foodgrain and off-farm growth, and even irrigation, did little to compensate.

Zones are big places, and mask much more localized effects. In India, slow-growing districts in the modern-variety period had in 1962-65 shown no worse initial land quality and yield, but much worse initial labor-productivity and hence poverty, than the faster grower districts (Bhalla et al. 1983, Table 17). Of course, widening productivity gaps have cumulatively disadvantaged poor farmers (and laborers) in the neglected districts. Even at

the village level, within similar (semi-arid) environments, inter-village differences in modern-variety benefits far outweigh intra-village differences. Caste and ethnic group do not appear to explain any of this (Gibbons et al., n.d., pp.194, 205, Herdt and Capule 1983, p.32). An additional productivity gap may also be emerging between men and women in agriculture, where task or land allocation is gender-specific, if male tasks become more capitalized or mechanized than female tasks or if female production of relish and reserve crops is pushed onto marginal or more fragile land.

This highly localized regional disparity, plus the known general problems (e.g., drainage of rainfed, especially upland, rice: inadequate N retention in semi-arid areas), suggest at least one approach to progress. First, find out why some villages in backward zones overcome the problems and do well with modern varieties (e.g., even in Orissa, 30 percent of rice was in modern varieties by 1978-9 (Herdt and Capule 1983, p. 49). Second, ask if institutional factors (fertilizer distribution, credit?), or modern-variety-ecosystem interactions, explain the successes. Third, shift research priorities towards stability in marginal environments (cf. CIMMYT 1983. p.VIII).

Where are shares of foodcrop research-budgets, either of centers or national programs, far below shares of foodcrop consumption, output, land or worktime? In general, center allocations for rainfed crops in Africa already exceed their proportionate contribution to output (chapter 2). But where they occur, do less than proportional allocations correspond to poor prospects of

research results and, if so, are there remedies, e.g. via researching modern varieties of alternative crops for these areas? For African research, the huge shortfall is for root crops (Judd et al. 1983, Lipton 1985). Can this be justified, or does it impede successful work by IITA for these regions? Similar questions throughout the international and national centers -- and much more work on arising from poor farmers' perceived needs, are essential to avoid neglecting either the poorest producer regions or the poorest consumers (section 8.3.3).

Research on irrigated areas may be running into diminishing returns, at least for poor producers, but much of the centers' professionalism remains concentrated there. National research systems (under urban pressures) stress irrigated areas, because they deliver surplus food, especially rice or wheat, to middle-income organized urban workers. Have the centers moved as far as they can to correct for that emphasis? One alternative of migration from rainfed areas has high costs, soon meets limits of absorption, and has nothing like sufficed to prevent deepening relative, and often absolute, poverty there.

8.4.5 Adoption and the research agenda

Research on small-scale farmers in modern-variety sorghum, millet, wheat and rice areas has repeatedly chartered who adopts: whether soon or late; over what proportion of area; with what other inputs; and with what farm yield, profitability and income. Sharply diminishing returns have set in to this type of research, much of it carried out by researchers outside the centers, and social scientists need to rethink their research agenda. Five reasons are advanced as to why such research reveals so little about how modern varieties affect poverty, even in modern-variety areas.

First, given the area, region, and crop-mix, size alone has limited effects on a farm's capacity to generate net farm income from the modern-variety crop; slope, terrain and water systems greatly alter such effects (Colmenares 1975, p.21, Cutie 1975, p.23). Second, while such capacity is related to returns from all farm activity (net of production costs), modern-variety crops' effects on other crops and non-farm outputs are almost unresearched. Third, such returns are only part of poor household net income from all sources and non-farm activity and modern-variety benefits do interact, sometimes favorably (Herdt and Mandac 1981, p.394). Fourth, such income is weakly correlated with net income per person; larger farms mean somewhat larger families, yet (given size of farm) larger families tend to be poorer (Lipton 1983a), and family size is often correlated with modern-variety adoption (Herdt and Capule 1983, p.32, Malla 1983). Fifth, modern varieties affect net disposable income per person not only via net income, but also via obligations -- debts, bribes and family labor requiring feeding (Cohen 1975. p.374) and by switching the distribution of resources between members of households.

Thus research in modern-variety areas should shift from size, adoption and yield issues to efforts to trace how modern varieties affect real disposable income per person in poor farm households. Since poor people gain from modern varieties mainly as food consumers, and lose from them mainly in non-modern-variety areas (section 8.4.4), and since the world's poor increasingly are landless laborers, poverty research related to modern-varieties should probably shift away from "farm households in modern-variety areas" to some of the issues raised in the following sections.

In summary, research that might restore balance would avoid some of the following problems that have beset many socio-economic evaluations of modern varieties effects on the poor:

(a) Asking the wrong questions, e.g., "do small-scale farms adopt modern varieties" instead of "do farmers with poor families gain from modern varieties".

(b) Looking only at first-round effects, e.g., "more modern-variety output cuts food prices to poor employees", but not e.g., "and employers may then reduce wages".

(c) Seeing the action only where it is, e.g., successful modern varieties may divert resources from unaffected, often poorer, regions, at the same time cutting farm-gate prices there.

(d) Isolating modern-variety effects, e.g., more protein from Opaque-2 maize need not bring better diets to undernourished children.

(e) Isolating individuals from groups and relationships, e.g., modern varieties may affect poor individuals by changing relations between lenders and borrowers, or between members of households.

(f) Isolating economic effects of modern varieties from their context, e.g., if populations grow, if landlords' power changes, this affects the poor interactively with major technical change.

8.5 Labor and the Modern Varieties

The distributional consequences of adoption of modern varieties for farmers are complex and somewhat ambiguous, depending on how operators of farms of different sizes act differentially, for example, in actions to seize scarce credit, water and fertilizer from the poor (Kryeger 1974). Absolute gains for laborers from modern varieties are less ambiguous but such gains, initially large, appear to be dwindling (Smith and Gascon 1979, Smith et al. 1985, Jayasuriya and Shand, 1985). Modern varieties raise labor-demand per hectare, especially around harvests (and for double-cropping), pushing up employment. But ample, mobile and growing labor-supply, and increasing mechanization in some areas, keeps real wage-rates from rising much. Modern varieties raise demand for land by less but usually land-supply cannot respond much, so rent and land values rise.

In summary, there are likely to be significant rises in labor use, but not in real wage-rates, big rises in land values and rentals and probable falls in labor's share of but not absolute value of income. Farm families, made less poor by modern varieties, take more leisure leaving a larger part of labor-income to landless hired workers. Unfortunately, the seasonal labor shortages linked to modern varieties, increasingly, induce labor-displacing inputs (threshers, tractors, weedicides) that also come into use in other seasons. The centers should perhaps try to steer research, and modern varieties, towards patterns that discourage such results.

8.5.1 Labor use, wage rate and factor shares

In the wake of modern varieties as rural income rise and job-markets displace self-employment, the proportion of days supplied to the workforce (adult participation) falls, and the proportion of workforce-days demanded, i.e., unemployment rises, (Dasgupta 1977a, esp. p.172). Developing country rural unemployment grows because population and thus workforce rise faster than participation falls (Lipton 1984). Labor demand linked to modern varieties has moderated this unemployment. Early observers of modern varieties found that they raised labor use per hectare-year by about a fifth (ADB 1977, p.60, Barker and Herdt 1984, p.38). As modern varieties spread to less favourable environments, yield impact and employment benefits fell.

But labor/output ratios have usually fallen too. The main reason, (a) mechanization outpacing migration, is discussed in the next subsection. Others include (b) rising costs of finding work and supervising hired labor, (c) institutional change that destroys traditional labor arrangements (Hayami and Hafid 1979), (d) more hopefully, growing off-farm work chances, (e) subsidies for labor-displacing inputs, and (f) most worryingly, research addressed to reducing per-hectare costs of techniques that use machinery and fossil fuels, helping to displace labor on big farms.

Despite recent declines, modern varieties impact on employment usually remains positive. But few significant rises (as opposed to fluctuations) in real wage-rates are found in Asian modern-variety areas (Kumar and Sharma 1983, Jayasuriya and Shand 1985). Extra work is absorbed by extra people, who

compete real wages down to near-subsistence. Without modern varieties, many more of these people would have been jobless or dead, especially as higher food prices would have pushed "subsistence" wages lower still, as happened in many non-modern-variety areas (Jose 1974, Parthasarathy 1974). Modern varieties mean a higher real wage bill -- but usually it absorbs less than 10 percent of extra modern-variety incomes, the rest going to landowners and input suppliers (Crisostomo et al. 1971, Burke 1979, Ahmed and Herdt 1981). The following additional considerations also bear on the issue of employment. Hired labor households, sharing the wage bill increased by modern varieties, are themselves increasing: mostly this is Malthusian, but sometimes extra modern-variety-based resources and power help "the village rich to turn the poor off their land" (van Schendel, 1981, p.245). Little is known about how modern varieties affect off-farm, or non-modern-variety crop, wage-rates or employment or about effects on labor in non-modern-variety areas. Finally, though "laborers" gain absolutely from modern varieties, particular vulnerable groups may lose. The above remarks are oriented to Asia and to some extent Latin America. More work is needed on these issues in Africa, especially where high rates of out migration particularly by males may induce new complications in the modern variety picture.

The impact of modern varieties on the structure of labor use can be considered in two convenient categories, namely, by groups and by timing. Hire labor as a group increases more than family labor (Visaria 1972, Barker and Herdt 1984, p.39). This helps the poor in irrigated areas where poverty is concentrated among the landless (Lipton 1983). Modern varieties also probably shift demand from casual to longer term hired workers, reducing numbers in poverty but increasing its severity for remaining casuals.

Some village data suggest that both trends reduce women's share in cash income. A systematic study in India, however, related total female labor positively to modern-variety rice in all three states surveyed (Agarwal 1984). There are many documented instances, particularly but not exlcusively in Sub-Saharan Africa, where modern technologies have differentially affected the structure of male and female labor use. One study of food farming among the Nigerian Tiv analysed differences in male and female labor roles, income sources and financial responsibilities and showed how adoption of the recommended technologies and package of practices would have raised women's labor input relative to men's but not provided them with a commensurate financial reward; since the potential for women to absorb labor increases of the magnitude required was limited, the net result was a decrease in the anticipated volume of farm household production (Burfisher and Horenstein 1985).

On timing, modern varieties usually help the rural poor by stabilizing labor demand, wages and employment within and across seasons (Dasgupta 1977, p.336, Barlow et al. 1983). Unfortunately, some center research such as that on threshers, transplanters and commercial weedicide potentially undermines this benefit, while work on fertilizer placement may strengthen it. Since post-harvest labor is especially at risk, screening of modern varieties for post-harvest characteristics, notably amenability to labor-intensive processing and protection, is desirable although admittedly difficult. Research on second-season crops has helped to increase total labor use. It could help to

avoid labor displacement if shorter-duration varieties were sought, even at some sacrifice of yields, thereby making threshers and tractors less attractive to speed up the turn-around between crops.

Between years, modern varieties have probably raised national-level variability of crop output, and a fortiori of labor hire, by raising the covariance among high-output areas (Hazell 1984). In almost every Asian village, however, farm employment, even in a bad year, is raised by modern varieties.

8.5.2 Modern varieties and the laboring poor: mechanization vs migration

Tractors, two-wheelers, threshers, even mechanization of irrigation, normally displace considerable labor (Binswanger 1978, Joshi et al. 1981, Farrington and Abeyratne 1982, Jayasuriya et al. 1985). Claims that they avoid this by raising cropping intensity usually collapse when modern varieties, water, etc. are allowed for (Agarwal 1981, 1984). Indeed, tractors may displace more labor in double-crop systems because animals and their care are more completely replaced (Cordova et al., 1981). But do the centers' activities forge, strengthen or break the links between modern varieties and mechanization? Machinery cannot usually be paid for, per hectare, out of very low traditional variety yields, and double cropping reduces tractor and thresher downtime and increases gains from timeliness. But should the centers work to develop, or cut the farm costs of, mechanical reapers — "a very profitable investment" (Moran 1982) because they reduced employment of poor

harvest laborers by 80 percent -- or tractors or threshers? In rare circumstances (such as in E. Zambia) such inputs can permit extra land to be farmed; or reduce drudgery, not employment; or create voluntary leisure for some farmers. But deeper unemployment for the bitterly poor, with little or no output gain, is a more common result.

Migration, unlike mechanization, eases seasonal modern-variety peaks by spreading work (to people from neglected areas), not destroying it. Typical migrants are either better-off villagers headed for towns, or the poor seeking farm work (Connell et al. 1976). Modern varieties affect these groups differently. Technology developers working in and with the centers probably should know more about how alternative modern-variety strategies and farm systems affect migration and hence wage-rates, incentives to mechanize, and jobs. For modern-variety gains to stay with poor workers, and not just machine-owners and labor-saving farmers, new farming systems should spread peaks to attract enough immigrants to restrain the development of seasonal wage peaks and hence labor-displacing mechanization. Some center research may have neglected or discouraged the migrant-employing response to seasonal labor peaks, and encouraged or cheapened labor-displacing alternatives. Doubtless some of the more "successful" engineering work discussed in chapter 17 could be so described, for instance.

While modern varieties cannot simply be absolved from any linkage with labor-displacing inputs at some times and places, they do initially raise the demand for labor, and cheapen food for laborers. Moreover, it is only because

a worker owns neither the land nor the machines, that he or she suffers when "displaced" by them. Population pressure and inadequate rural off-farm activity worsen the suffering.

Therefore, the centers' research should significantly be directed towards varieties and technologies with increased labor/land and labor/capital ratios, in the contexts of land and asset ownership and of population growth facing rural employees. These are in Asia now, and in Africa soon will be, a growing majority of the poorest. Saying that modern varieties and the centers with which they are associated are not to blame for those contexts, while true, does not come to grips with the death, pain and poverty that unemployment causes. An integrated research approach to such problems should presumably be high on the agenda of both national and international concerned organizations.

8.6 Poor People's Consumption and Nutrition: Impact of Modern Varieties

8.6.1 Food production and nutrition

Changes in food production affect nutritional status to the extent that food consumption of malnourished individuals is affected. The nutritional effect of changes in food supply depends on the distribution of effects which, in turn, depend on how the supply change occurs - which commodities, how prices are affected and whether there are simultaneous changes in incomes of malnourished groups.

Although many factors contribute, insufficient energy and protein intakes are usually a result of inadequate household food acquisition power and behavior. "Household food acquisition power" combines the effects of household self-provisioning, purchasing power, food prices, food availability and resource control (Pinstrup-Andersen 1985). Increase in food production resulting from technological change may increase self-provisioning and purchasing power (of producer households), reduce food prices (thereby adding to food acquisition power of nonproducer households) and will increase food availability. Imports, food subsidies or direct distribution each lack one or another of these effects.

In low-income countries, the poorest 20 percent of people spend 60 percent and upwards of their income on food and, even then, are able to purchase much less than the amount judged nutritionally sufficient. Thus, production increases that drive down real food prices help the poor the most. The relative importance of individual commodities in the food budget of the poor varies among countries. In some, one staple may account for 40-60 percent of food energy and expenditures, while in others no single staple is dominant.

Table 8.1 illustrates the differences in the contributions that two staple foods make to the diets of the 10 percent poorest and the 10 percent wealthiest sectors of several countries. In the Sudan, people in the lower of these groups consumed less than half the rate of energy judged to be sufficient, and obtained about 20 percent of this energy from sorghum: the higher groups

Table 8.1 Proportion of food energy from and of expenditures on two principal staple foods in five developing countries

		Lowest 10% per capita income		Highest per capita income[a]	
	Staple	% of energy	% of expenditures	% of energy	% of expenditures[b]
Colombia	Rice	17.6	12.4	14.5	6.1
	Cassava	7.9	5.6	4.1	2.0
Egypt	Wheat	47.3	12.6	38.7	2.1
	Maize	12.3	2.2	10.4	0.3
Sri Lanka (Urban)	Rice	47.2	26.6	33.4	7.8
	Coconut	16.8	7.3	15.0	2.7
Sudan	Meat	28.0	13.6	34.4	11.0
	Sorghum	19.5	6.7	5.9	2.3
Thailand	Rice	89.3	34.5	48.1	1.8
	Wheat[c]	0.1	0.2	2.7	1.1

Source: provided by IFPRI Food Consumption and Nutrition Program.

a For Colombia, data here refers to average of all income groups, for all other countries data refers to the highest 10% income group.

b Data show % of total food expenditure on each item for Colombia, and % of total household expenditures on each item for other countries.

c Consumption of cassava, millets, sorghum and other root crops all below 0.5% of total food energy in Thailand.

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of consumers obtained about five percent of their energy from sorghum. All groups got a higher proportion from wheat which is clearly a preferred staple, because its consumption increases as incomes rise. Thus, even though sorghum is a "poor person's crop", changes in wheat prices may have a greater impact on the poor than changes in sorghum prices. These kinds of counter-intuitive effects are also observed in other countries.

Because food accounts for such a high proportion of poor people's expenditure, reductions in food prices have a greater relative benefit to poor people than to the wealthy. The increase in consumption rate results when food prices fall and depends on preferences and other needs of the households concerned, but generally a large fraction of additional income goes to food purchases in low income households. In developing countries for which data are available, the same reduction in prices leads to twice the relative increase in real income for poor households as for the rich (Table 8.2).

Modern varieties have moderated the threat of rising real food prices. In the early 1980s, if they had been replaced by traditional varieties (with other inputs unchanged), yearly developing country rice output would have been 10-27 Mt less, and wheat 7-20 Mt (Pinstrup-Andersen and Hazell 1984). Other crop modern varieties added at least 3-5 Mt. Other inputs, worth applying thanks to modern varieties, probably raised the food output increment by over 50 percent. Yet in India, with an increment of perhaps 12 Mt, yearly food

Table 8.2 Impact of a 10 percent decrease in the price of food on real income of low and high income population groups

Country	Percent increase in real income: Lowest 10% per capita income	Highest 10% per capita income	Source
Sri Lanka	8.5	4.1	Sahn (1985)
Thailand	6.0	2.0	Trairatvarakul (1984)
Egypt	5.6	1.0	Alderman and von Braum (1984)
India	7.3	2.9	Murty (1983)
Funtua, Nigeria	7.7	6.5	Pinstrup-Andersen and Uy (1985)
Gusau, Nigeria	9.0	5.7	Pinstrup-Andersen and Uy (1985)
India[a]	5.5[b]	1.2[c]	Mellor (1978)

Source: IFPRI Consumption and Nutrition Program

a Foodgrains only.
b For the lowest 20 percent.
c For the highest 5 percent.

availability per person has barely outpaced population. Apart from feeding the larger population, extra modern-variety output was used largely to replace imports and build stocks. Some countries' trade policies "fixed" food imports: in Colombia, therefore, rice modern varieties raised availability, cut prices and, in 1970, raised incomes in households with income below $600 by 12.8 percent — over half at the expense of producers, especially in non-modern-variety areas (Scobie and Posada 1978, and see Feature on Colombia). Poorer producers' price losses are reduced because they (a) switch into other crops, if modern-variety crop prices fall much faster than unit costs of production, and (b) "internalize" some consumer gains by eating large parts of extra modern-variety output themselves (Hayami and Herdt 1977). Poor consumers, including such semi-subsistence producers, usually gain most if modern varieties affect goods that are little appreciated by consumers with higher incomes such as cassava in Brazil or Colombia (Pinstrup-Andersen 1977, Pachico 1981).

But the poor's consumption gains have limits. (a) If income (including initial modern-variety) growth favors the rich, modern-variety output will tend to displace imports, not cut domestic prices, (b) If modern varieties restrain staple-food prices, employers can restrain money-wage rises, especially with plenty of underemployed and mobile workers, leaving real purchasing-power little improved, (c) In non-modern-variety areas, poor farmers (often selling wheat or rice to buy inferior foods) and their employees lose consuming-power as the price of modern-variety crops fall, although in middle-income developing countries they are outnumbered by poor urban gainers (Scobie and Posada 1978), and (d) By directing some effort on protein and "food quality", it is conceivable that the centers may have delayed modern varieties' potential to provide cheap food energy to poor consumers, just as thresher/reaper/weedicide research has partly eroded modern varieties potential to provide labor income to poor employees.

Modern varieties have, by moderating food prices, been the main factor improving the nutrition of the poor of the developing world. Such improvement is clearly close to the centers' central objective. How they can help depends on who is vulnerable to what sorts of undernutrition, where, when, by how much, and with what trends. Correct perception of undernutrition implies regional, commodity, and varietal priorities. Some modern-variety research resources have been diverted to topics unrelated to the main causes and incidence of undernutrition. Poor at-risk consumers need preferably cheaper, more food energy, stabler and more easily absorbable — rather than, say, high-lysine maize.

Major modern-variety-based rice and wheat improvements have prevented mass starvation in much of Asia. Wheat progress has displaced pulses, but wheat gives much cheaper dietary energy -- and 90-95 percent of undernourished people lack energy more than protein. But in Africa, and in semi-arid Asia, modern varieties of wheat and rice have done much less for poor consumers; they eat mainly sorghum, millet, maize and cassava. Hybrid maize, which has partly displaced sorghum, a less vulnerable crop, has progressed very slowly since 1970. Sorghum progress is confined to major, recent advances in limited places and seasons, mostly in India.

Inferential evidence suggests that rice and wheat modern varieties have substantially improved urban, irrigated small-farm rural, and (in lead areas such as the Punjab) irrigated landless rural nutrition in Asia and Latin America; but that rural Asians in unirrigated areas (with some Indian exceptions thanks to kharif sorghum, pearl millet and finger millet) suffer at least as severe energy deficiencies as 10-15 years ago, whereas the poorer rural African eats considerably less, and with greater fluctuations. As and when adopted, IITA'S mosaic-resistant cassava modern varieties will help the latter energy problem -- as they have in Indonesia -- but cassava, exceptionally, does create protein problems as a main staple. Since legumes produce more costly protein (and much more costly energy) per hectare than cereals, legume research has fewer nutritional benefits than is often supposed, but can reduce dietary monotony and vulnerability to drought. The centers working on food legumes might usefully identify further how they can best help nutritionally vulnerable target groups.

The main nutritional deficiency is energy. The main vulnerable group comprises the ultra-poor (10-15 percent in low-income countries), especially under-fives. They ingest mainly coarse grains, roots, cheap wheat or rice modern varieties, or breastmilk/gruels based on these. Risks from undernutrition are synergistic with illness, and greatest in lean seasons and years. Under-fives are heavily over-represented among the ultra-poor (Schofield 1979, Chambers et al. 1981, Lipton 1983a), who comprise most rural landless, unskilled urban jobless and households headed by women, plus many households of African small-scale farmers and Asian micro-scale farmers without access to irrigation.

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The centers seek to develop new agricultural technology to improve human welfare. It is therefore pertinent to enquire whether there is evidence that human welfare has been enhanced following the successful introduction of new technology. The case of rice in Colombia affords such an opportunity.

In the mid-1960s, almost all of Colombia's irrigated rice production was based on tall varieties with yields of less than 3 t/ha. Today irrigated rice production is based solely on modern varieties and the yields are over 5 t/ha. Colombia today produces over 1 Mt more rice than it would have done with traditional varieties on the irrigated areas. Earlier studies have shown that the annual rate of return to investment in rice research was between 80 and 90 percent.

Of particular interest is the impact of this increase in rice production on human nutrition. It is widely recognized that nutritional status reflects education, access to health services, distribution of potable water, and occupation, as well as food intakes. To attribute changes in some measure of nutritional status solely to changes in food consumption would be quite erroneous. For this reason, the change in energy intake is used as a measure of the impact of the modern varieties.

The Department of National Planning and the National Statistical Office in 1981 conducted a survey of 9000 households representing over 90 percent of the Colombian population. The survey gathered information about (a) household size and age-sex composition, (b) location (rural/urban), (c) food expenditure, and (d) food consumed, including subsistence production. A 24-hour recall food consumption survey was also conducted for 3000 households. Based on the overall results of the survey, the summaries of Table F8.3 were constructed.

Rice represents 6 percent of total food expenditures on average but, among the lowest income group, it represents 17 percent of total energy consumption.

From the 9000 households, those with incomplete data on income were excluded leaving 6093. Of these, those comprising the lowest 30 percent of incomes were selected, making a total of 1828 households. Extreme values of prices and/or energy intakes were excluded leaving 678 urban and 1024 rural households. The analysis was restricted to 10 major food items. The shares of energy are reported in Table F8.4.

The first part of the study (conducted by Muchnik 1985) focused on the impact on total energy consumption of rice consumers. The consumption of each food was expressed as a function of the prices of each of the 10 foods, family income, family size and the proportion of children under five years. From these estimates it was possible to derive a relationship between changes in energy intake and the price of rice.

Table F8.3 Summary nutritional data

(a) National expenditures and consumptions of major foods

Food	Share of total food expenditure	National annual average consumption
	percent	kg/adult equivalent
Dairy products	10.1	71
Plantains	5.0	69
Fruits	6.7	62
Potatoes	5.0	56
Sugar	8.7	54
Vegetables	7.1	41
Rice	6.1	40
Beef	16.7	32
Cassava	2.0	25

(b) Protein and energy consumption averages by income group

Income inter-quintile group	I	II	III	IV	V
Energy (cal/day)	1910	2580	2960	3200	3120
Protein (g/day)	40	60	74	83	85

(c) Share of selected foods in energy consumption by income (percent)

Food	Income					
	I	II	III	IV	V	National average
Sugar	20	20	19	18	18	19
Rice	17	15	14	14	13	14
Fats	9	10	12	13	14	12
Root Crops	15	13	11	9	7	11
Maize	9	8	6	5	5	6
Dairy Products	4	6	6	6	7	6
Meat	3	5	6	6	7	5

Table F8.4 Share of total energy intake of selected foods among the households comprising the lowest 30 percent of incomes

(percent)

Food	Urban	Rural
Sugar	22	20
Rice	20	16
Potatoes	7	6
Cassava	6	8
Beef	6	4
Plantain	9	10
Maize	8	9
Bread	5	2
Beans	3	2
Milk	4	4

The introduction of modern varieties expanded output and, as foreign trade was insignificant, it augmented domestic supplies. The rate of growth in rice supply was faster than the growth in demand from rising incomes and population so that the real price of rice to consumers fell. Alternatively viewed, the price of rice would have been very much higher had it not been for the expansion of supply engendered by the introduction of modern varieties.

This result depends crucially on the assumption that the government would, in fact, have allowed the rice price to climb to these levels. Given the importance of rice in the diet of all Colombians, it is improbable that such a strategy would have been followed. This illustrates the dilemma which faces an analyst of the impact of a particular policy - namely, what would have happened in its absence. In the absence of modern varieties and with the concomitant tendency for prices to rise, it seems reasonable to expect that some intervention would have occurred. This might have taken various forms including subsidies on the price of rice to low income consumers or increased supplies through imports. The actual policy corresponded to a closed-economy situation with no trade in rice. The prices that would have prevailed under an open economy with rice imports were estimated on the basis of the average c.i.f. price paid by Latin American importers adjusted for tariffs, transport costs and marketing margins.

The average annual decline in rice prices from 1969 to 1981 due to the modern varieties was 55 percent and 14 percent under the closed and open economy policies, respectively.

The increased energy intakes were estimated based on a high and low measure of the response to a fall in rice prices. Under the low response, total increase in energy intake would have been less than 1 percent per capita a year in an open economy. Using the higher estimates of response and a closed economy, the energy intakes rose by 8.7 percent in the urban and 15.3 percent in the rural areas, i.e. on average over the period 1969 to 1981, per capita energy intakes were higher by 8.7 or 15.3 percent per annum. These represent the upper bounds of the feasible estimates. The results allow for any declines in the consumption of nine other major foods arising when consumers substitute more rice for other foods in response to the cheaper rice, i.e., the calculations reflect a "net" increase in total energy intakes.

There are two important features of these results. In the first place, when a commodity represents a significant share of energy intake, the introduction of new technology which increases supplies and lowers price can lead to an important increase in per capita energy consumption. Given that the average per capita intakes of this group in Colombia were below the FAO standards (2,420 k cal/capita/day) and, within the group 42 percent of families did not meet the Colombian standard of 1,970 k cal/capita/day, it is clear that increases of the magnitudes estimated here are potentially significant. Second, however, it must be stressed that the outcome is sensitive to the counter-factual hypothesis: what would have occurred in the absence of the new technology? In the Colombian case, it is useful to demonstrate the effect of trade policy on the outcome. If a good enters world markets, its price is

determined outside the domestic economy. In a small open economy, domestic consumers will not necessarily directly benefit from technological change which increases food production.

The introduction of new technology also affects the income of producers (both adopters and non-adopters) and the demand for labour. As a result of the introduction of modern varieties, the irrigated sector assumed much greater importance in Colombian rice production. Irrigated production needs only about two-thirds of the number of labour units per hectare as does the traditional manual upland rice system. This constitutes a decline in the demand for labor that would represent a loss of income to laborers made up of lower real wages and fewer jobs. By 1981, the income of landless workers was estimated to have been 1.03 percent lower than that which would have prevailed in the absence of new rice varieties. This loss of income is estimated to result in a drop in energy consumption of one tenth of one percent (0.1%) if evenly spread across all landless workers. This is the upper bound on the effect of landless laborers as it assumes that the rice sector is sufficiently large to affect rural wages (a fact which is highly improbable) and it ignores the benefits accruing to this group as rice consumers through lower real market prices. The latter effect, if these workers are representative of rural low income people, amounts to between 1.2% and 3.8% in an open economy, so that the net effect on landless workers was an increase of between 1.1% and 3.7% in food energy consumed.

Finally, there is a group of small farms in the upland sector which faced lower prices and no technological advances. As a consequence, their numbers fell by about 5000. Based on the fall in prices, their incomes are estimated to have fallen on average by 87 percent between 1969 and 1982 under a closed economy, or 41 percent under an open economy. When these estimates were combined with the response of energy intakes to total income changes, it was found that energy intakes among this group would have declined between two and five percent in an open economy and four and ten percent in a closed economy. The lower real prices would offset these declines by between one and four percent in an open economy and by between five and fifteen percent in a closed economy. Again, these must be taken as upper bounds as the estimates are based on the assumption that these farmers had no alternative crops to grow in the face of falling rice prices. It is assumed (conservatively) that they simply maintained their existing level of rice production and suffered the loss in income stemming from lower farm-gate prices.

These results again emphasize the importance of policies in determining the magnitude and distribution of benefits from new technology. A country that protects its non-farm sector and maintains an overvalued exchange rate will discourage output and productivity growth in agriculture. Furthermore, when new technologies are introduced into such a setting, consumers will benefit at the expense of producers, and non-adopters will be particularly disadvantaged. In contrast, in a more open economy the price effect of new technology will be less, and producers will be the primary beneficiaries. Their real income gains

will result in an initial rise in total energy intakes. As their spending on other goods rises, so will real income in other sectors leading to indirect increases in energy intakes among the non-farm sector. While improving human nutrition through increased food intakes amongst the low income groups is unquestionably a desirable goal for the centers, it must be stressed that the final outcomes do not depend solely on the introduction of new agricultural technology. The linkages are complex; different groups will benefit to different extents and, above all, the economic policies of the country can have an overriding effect on the magnitude and distribution of any nutritional improvement.

END FEATURE

8.6.2 Variability, vulnerability and quality

Modern varieties have raised year-to-year national-level variability of cereal output slightly, though on-farm disaster risk has probably generally lessened. But, since farmers meet family needs first, sales for off-farm consumption fluctuate much more than production, as do prices, unless imports are used to moderate such fluctuations. Vulnerable groups' consumption outside modern-variety areas can become very vulnerable. Stocks become more important and, thanks to extra modern-variety output, more feasible, justifying some research on storage characteristics.

Modern varieties have reduced seasonal consumption variability, because output gains (except for kharif sorghum in India) are heavily concentrated in the water-controlled, non-rainy season. But the costs to poor consumers of year-to-year price instability suggest priority for raising yields of more robust crops, especially drought-resistant millets and sorghums to compete with modern maize varieties in African farming systems.

Preschool children, and pregnant and lactating women from poor homes require particular research attention because of their relative vulnerability. More output has helped them by reducing intra-family competition for food, and greater seasonal stability has helped too. But research has ignored the possibly special role, for these vulnerable groups, of modern-variety nutrients and work-inputs. Potentially relevant albeit very challenging issues, especially for national programs in countries where vulnerability is high, include: which processes could cut cost, time, or risk of contamination in

preparing food, especially weaning food? Which crop-mixes and modern varieties, in the context of total diets and activity of vulnerable groups, might help to improve quantity, quality and absorbability of breast milk, and for energy density, nutrient mix, and absorbability of cheap weaning foods? How does timing of seasonal food (and mother's work) interact with these issues? Crops, and perhaps varieties, differ in these respects, as well as in fiber content and anti-nutritive factors affecting them indirectly.

The menu of conventional modern-variety nutrition research has sometimes been of questionable appropriateness through some work on nutrient quality and palatability. Improving maize amino-acid mix via Opaque-2 genes has taken considerable research resources. Protein balance and enrichment works wonders for storage pests, but vulnerable humans do not live by modern-variety cereals alone. Opaque-2 maize modern varieties now yield no worse than others but, to obtain the extra lysine, have the poor unknowingly sacrificed as research resources were switched from energy yield and stability? Probably little, in the judgment of Lipton and Longhurst (1985). ICRISAT, fortunately, established that amino-acids did not constrain dietary adequacy among vulnerable groups, thus avoiding major wastes (Ryan 1984). Only where root-crops or bananas are major staples -- and where legumes are unimportant -- is it likely that protein research can contribute significantly to poor people's nutrition.

Breeding for palatability, color, and appearance (Ryan 1984) threatens the price discount which makes modern varieties so important for poor consumers. It can make sense if many poor producers, or employees, depend on selling these

crops to the rich. But in general it is yield and stability of cheap food energy that the poor need most. If researchers collaborating with the centers seek more sophisticated quality or nutritional goals, it is on the needs of the most vulnerable groups that they should concentrate in order to seek maximal social relevance.

8.7 Further Insights to the Modern Variety-Poverty Mystery

Despite reservations, both the physical features and the observed effects of modern varieties on smallholders, laborers and consumers seem generally pro-poor. How, then, is it possible that in most of Africa there are few modern varieties and deepening poverty (Ghai and Radwan 1983), and that in Asia a massive spread of modern varieties has been compatible with rising real income-per-person but with little dent on the incidence or severity of poverty (ADB 1977, p.63, Lipton 1983a)?

The approach in this chapter so far has involved taking separate aspects of modern-variety impact such as on employment, small farms and nutrition, and treating them as simply additive. This leaves some unanswered questions: for example, the consumption studies suggest that, while consumers benefit from modern-variety-induced price reductions, producers lose 50-60 percent of what consumers gain (Scobie and Posada 1977, Evenson and Flores 1978), yet the production studies claim producer gains too. More holistic ways to look at modern varieties in their socio-political context are available and may suggest useful new departures. Such ways are offered by economics, political

economy and comparative history and some of these, particularly from the latter are now considered.

Several different types of models have been developed by economists for attempting to examine the consequences of changes beyond the sectors in which their first effects (such as crop productivity gain) occur. Some are neo-classical in that they are predicated on assumptions that all inputs are fully employed and, except for land, freely mobile among activities (Binswanger and Ryan 1977, Binswanger 1980, Quizon and Binswanger 1983). Such models still give unclear predictions of impact on distribution between labor and capital and depend on the exposure of an economy to foreign trade. Whether they show that labor-using and land-saving technical changes like modern varieties benefit labor, depends on the employment effects of any extra equipment involved. Research priorities oriented to assisting the poor could be clarifed, by further development of computable models of this class.

Other more general equilibrium models can trace how extra spending by people initially enriched by modern varieties goes through successive rounds to create extra incomes for others, rich or poor. In a regional model of this kind modern-variety producers in Malaysia generated further 80c of income for every dollar of their extra modern- variety initial income (Bell, Hazell and Slade 1982). Some such effort to trace successive spending rounds, however, seems necessary to a holistic view of the impacts of modern varieties.

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Market signals and factor movements, rounds of spending and rounds of production, all significantly affect modern varieties' impacts on the poor and all are neglected in the more simplistic additive approaches of earlier sections of this chapter. While still demanding of data and skill to investigate, all could help the centers and their partners if applied to their problems. In this context it should be noted that the studies reviewed in this section were initiated by or conducted by social scientists working at or linked to the centers, which underscores center concerns for these issues.

In many developing countries the government is a major trader in food staples. Modern varieties thus change its budgetary position. This affects demand, trade, and hence prices, spending patterns and output. Also, modern-variety-induced price changes induce changes in wage-rates. This affects parastatals and, again, government budgets. Both sequences can greatly alter the poverty impact of alternative modern-variety strategies. Examination of such sequences could well further illuminate anti-poverty work at the centers.

Apart from a few distinguished village studies (Hart, n.d., Frankel 1972, Hayami 1978, van Schendel 1981) and some center farming systems work (Collinson 1982, Ghodake and Ksirsagar 1983, Hartmans 1985) there is little work on how modern varieties affect income (let alone status or power) flows and balances within local communities. Farming systems research (chapter 16) is one way forward. But off-farm production, consumption and leisure activities, and transaction relations with particular members of the community, also may substantially affect modern varieties' poverty impact. Some examples exist (Hayami and Kikuchi, 1981) but the issues deserve more attention of analysts in the centers and the national research institutions.

The approaches reviewed to this point do not inform how modern varieties interact with national wealth and power structures. Marxist analysts (e.g., Cleaver 1972, Byres 1972, 1981, Rudra 1978) ask if modern varieties advance rural societies from pre-capitalist formations, formalizing wage-contracts, and polarizing rural communities into capitalists and landlords. The approach, like its predecessors, may err by assuming that large farms have special advantages in using modern varieties. Also, modern varieties were preceded in the Punjab by polarization (and tractorization), and in Java by formalized labor contracts (Chadha 1983, Hart n.d.). The long debate in India about mode of production has involved neo-classicists and Marxists in looking constructively at how modern varieties and power-structures interact within socio-political systems to affect poverty. However, careful scholars stress that there is no general, context-neutral link of modern varieties to class action or to unrest (Byres 1977, Harriss 1977).

Historical methods might possibly help society and its institutions such as the centers to go beyond seeking modern varieties and related technologies that would help the poor and to develop improved technologies and farming systems "poor-friendly" in the real world. Historians have looked at how big agro-technical change systems or "agricultural revolutions" affect the poor. According to their view of the work of historians, Lipton and Longhurst (1985) identify four agricultural revolutions: the Neolithic, spreading southwest and north in Europe from 3500-700 B.C., when hunter-gatherers became farmers: the medieval European (600-1200 A.D.); the 18th century (actually 1650-1850 for N.W. Europe): and today's modern-variety-based green revolution. Four

criteria for identifying such revolutions are: (a) sharply accelerated growth of farm output, or productivity of a scarce input; (b) similarly for all inputs, i.e. discontinuous technical change; (c) linkage of such change to social or political transformation, and (d) major change in mass poverty.

An agricultural revolution is thought worthy of its name when it affects many people and big areas. The medieval revolution took hundreds of years to cover a nation, but was a sudden transformation for each adopting community. Because farmers and villages learn from near neighbors, such major changes concentrate regionally, pulling leaders ever further ahead. Norfolk led England's medieval and 18th century agricultural revolutions (Campbell 1983, Parain 1966, p.179), Riches 1937, pp. 8-17) rather as N. W. Mexico, central Java (Franke 1972), and the Punjab (Lowdermilk 1972, Randha 1974) have pulled away in the modern-variety era on the basis of prolonged earlier innovation leadership.

Much of history suggests that lead regions in an agricultural revolution learn, accumulate, and thus leave the others ever further behind, contrary to the hopes sometimes fed by the assumptions underlying many models used by economists (Myrdal 1958). If so, stronger corrective policies will be needed to help the laggard regions. The international centers, with their relative independence from rich-region pressures, are a special feature of the present revolution. They should, perhaps, gear research more towards backward regions which, on the historical evidence, otherwise will tend to fall further behind.

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Can anything be done to counteract such tendencies? In normal times, with normal science (Kuhn 1962) producing a steady stream of innovations, these are probably induced by demand (Hayami and Ruttan 1971). This will come mainly from richer people (and regions), for better-tasting foods and often, where hired labor is troublesome even if not scarce, for labor-displacing methods (Grabowski 1981). In an agricultural revolution, new farming paradigms come from clusters of discovery: the supply side of science. Thus the 18th century revolution in England, far from releasing labor for industrialization, was based on discoveries that were land-saving (laborer/farmer ratios hardly changed) and that created new chances for profit, instead of responding passively to existing scarcities or landowners' preferences (Deane and Cole 1967, p.52, Mingay 1968, pp.25-26, Overton 1979. p.375, Turner 1984, p.225). Similarly the modern-variety aftermath of Mendel (and Crick and Watson?), and the significant historical novelty of the international centers, permits more than passive responses to wealthy farmers' or rich consumers' demand.

Growth of total factor productivity was measured to have accelerated sharply in Japan (1880-90), the U.S.A. (1885-1900, 1938-60), and, following modern varieties, the Punjab (1965-70) (Hayami and Ruttan 1971, p.116. Mohan 1974, p.A-98). Such growth measures come from analyses that may be flawed by omitted factors (Schultz 1964), scale economies, a "coefficient of ignorance" (Balogh and Streeten 19??), as well as discontinuous technical progress. Has such growth a less mechanistic, yet objective, indicator?

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Agricultural revolution innovations are, in principle, not seriable (Shackle 1952) (the farm system changes, ruling out piecemeal experiments), not separable (the package is all-or-nothing), and not single-unit (adopters must act together). In practice, only the Neolithic and medieval revolutions meet these criteria (White 1962, Bloch 1966, pp. 242,276, Parain 1966, p.144, Pigott 1981, p.31). Eighteenth century innovations, while bringing more dramatic growth acceleration, were largely gradual, piecemeal, and individual (Riches 1937, pp.5-16, 77-81, Mingay 1968, p.11, Jones 1974, p.88). So are the modern varieties. They rest on repeated waves of pre-modern-variety seed innovations (FAO 1971, P.6, Hayami and Ruttan 1971, pp.158-9, Carr and Myers 1973, p.32, Saxena and Jadawa 1973, p.65). They are set in eminently separable psuedo-packages (Lipton 1979), from which farmers can select by seriable, tiny experiments. Except for timed water supplies, they are single-unit, not resting on neighbors' decisions.

Neolithic, medieval, 18th century, modern varieties: each revolution has involved faster growth than its predecessor, yet smoother technical change. Thus revolutions are increasingly feasible for seriable, separable, single-unit (see previous paragraph) adoption by the poor, but decreasingly associated with rural political transformation, and thus likelier to provide benefits for existing power-structures (even if the agricultural revolution is apparently pro-poor). The expectation is for poverty to decline, but inequality to increase.

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At the local level, the modern varieties are like the 18th century revolution in that the new technology did not seem to need or to further, and in practice was not linked to, major change in ownership or organization of farm labor, capital, or power. New modern-variety-linked resources in E. Asia have drastically changed the possibilities of industrialization, rather as the 18th century revolution did in N.W. Europe. Surpluses to invest, food for workers, laggard regions unable to adopt the new methods, and forces to mechanize later: all describe both what the 18th century revolution in England (a little later in France and Prussia) did for national industrial structure and, with allowances for population explosions, what modern varieties may now be doing in Asia.

To conclude these interpretations of history, without modern varieties the poor of developing countries would have been worse off. However, to survive in the face of population increase, land inequality, and industrial country research to cheapen tractors and weedicides and dairy foods, the poor need innovations that help them to accumulate power, assets, or labor income: not only (as modern varieties have achieved) to lose them less quickly. What they need differs according to continent and to their characteristics (landless, semi-arid resource-poor farmers, urban jobless) but modern innovations probably need to be more sharply focused towards these poor people.

The international centers are a new fact of life, not found in earlier agricultural revolutions. Their greatest comparative advantage is relative immunity from the balance of short-run national political forces for research

to respond to the factor scarcities and crop priorities not of the poor but of the powerful. There are important lessons of this history for the centers. Given the particular political system, and each place's poorer target groups, modern varieties and other inputs, methods and outputs can be designed so that the poor can own, use, or control them. For example, male laborers, among the poorest in Bangladesh, gain from systems requiring hand-pumps (Howes 1982). Mini-farmers, still most of the very poor in Karnataka, are likeliest to gain from modern varieties of finger-millets (Rajpurohit 1983). In Colombia, where most of the poor are in towns, cheaper modern-variety rice helps, but more productive maize may help them most (Pinstrup-Andersen 1977). Each set of research priorities has to be reviewed by asking, not only the questions of sections 8.4 to 8.6, but also the question suggested by historical agricultural revolutions: in each major type of concrete situation, who will control the innovations, the systems that allocate them (not only markets), and the spread of gains from them to the poor?

8.8 Coda

* Research has sought modern varieties helpful to the poor by using more labor and supplying cheap food energy. These effects on the poor are real and good. But most of Africa is without modern varieties and is poorer than in 1970, and the incidence and severity of poverty in S. Asia are little changed despite modern varieties. Diagnosis of means to alleviate poverty in these situations increasingly needs to start from the total context of typical poor households.

* As newer modern varieties are bred to resist pests and disease, their advantage over traditional varieties at zero fertilizer has increased even under moisture stress. Still, at zero fertilization, this risks "soil mining". Moderate yield advantages of most modern varieties at zero or low fertilization can be outweighed by price discounts below traditional varieties, and lower straw yield.

* Modern varieties with low photo-period sensitivity thrive despite variable day-length. This permits multiple cropping and smoother flows of food through the year. The poor gain most, since they could seldom save or borrow against lean seasons. But local specificity, not wide adaptability, is now needed.

* Modern varieties increasingly resist moisture stress better than traditional varieties. Millets and sorghum are bred for rigorous root systems. Wheat producers in Pakistan and Tunisia, and rice producers in the Philippines and Bangladesh, have often adopted modern varieties mainly for drought resistance. Most of the poorest people of the world live in vast areas of unreliable rainfed rice, or of semi-arid crops, and most of these areas remain in traditional varieties. Extra targeted research is surely needed.

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* Some early modern varieties were indeed "insect pest museums" but most later ones now have better resistance than traditional varieties. Currently, yield increases are bought mainly by raising robustness, not by sacrificing it to yield potential. However, weed research seems to receive few resources. Rats, bird and other vertebrate pests are rather neglected by the centers.

* The narrow genetic base of modern varieties is a danger that is being tackled by the centers. The centers have unprecedented, freely accessible germplasm collections, and have used some wild races in breeding.

* Early studies clearly showed large-scale farmers adopting modern varieties much more readily: later work has shown that small-scale farmers were catching up, often leaving the bigger ones, however, with 'innovators' rents. As for tenure, owner-farmers do not adopt more than tenants, unless, as often happens, tenants get less credit per crop unit area. Small-scale farmers may adopt later because they avoid risk until they have seen their wealthier neighbors succeeding with modern varieties or because they cannot get scarce inputs at first.

* Small-scale farmers ultimately adopt as much and as intensively as others. Having more family labor per hectare, they may get higher yields. There is no general link of modern-variety adoption or yield to largeness or owner-occupancy.

* Areas that have not much used modern varieties have done badly. Poor non-adopting farmers and their employees lose absolutely when burgeoning output depresses prices. Yet, in non-modern-variety areas with poor soils, initial poverty is worse, and less unequal so that the chances of fairly shared gains would be better, if modern varieties do eventually take off.

* Modern varieties raise labor-demand per hectare, especially around harvest, pushing up employment. But ample, mobile and growing labor-supply keeps real wage-rates from rising much. Modern varieties raise demand for land by less, but usually land-supply cannot respond much, so rents and land values rise.

* Few significant rises in real wage-rates are found in modern-variety areas. Extra work is absorbed by extra people, who compete real wages down to near-subsistence. Without modern varieties, however, many more of these people would have been jobless, or dead.

* Developing, or cutting the farm costs of mechanical reapers, tractors or threshers reduces employment of poor harvest laborers. For modern-variety gains to stay with poor workers, and not just machine-owners and labor-saving farmers, new farming systems should spread labor peaks to attract enough immigrants to restrain seasonal high points and hence labor-displacing mechanization.

* In low-income countries, the poorest 20 percent of people spend more than 60 percent of income on food. Its demand and hence price is pushed up by growth of population and of income per head. Modern varieties have moderated this price threat. Poor consumers, including semi-subsistence producers, gain most if modern varieties affect crops such as cassava that are consumed most by poor people.

* Improving amino-acid mix in cereals has taken some scarce research resources. But vulnerable humans do not live by cereals alone. Only where root-crops or bananas are major staples, and where legumes are unimportant, can protein research contribute significantly to poor people's nutrition.

* Without modern varieties the poor of the developing world would have been worse off. However, to survive in the face of population increase, land inequality, and industrial country research to cheapen, say, tractors, weedicides and dairy exports, the poor need innovations that help them to accumulate power, assets, or labor income: not only to lose them less quickly.

* Preschool children, and pregnant and lactating women from poor households require particular research attention because of their relative vulnerability.

* Modern varieties have, by moderating food prices, been the main factor improving the nutrition of the poor of the developing world.

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9 HUMAN RESOURCES

9.1 Introduction

The CGIAR system recognizes the primary need for developing countries to improve their own capacities to conduct research and is engaged in many different efforts to improve that capacity. These activities can be subsumed under the general term of human capital enhancement. More narrowly specified they include training, education, conferences, workshops, provision of publications and other activities that transfer knowledge or contribute to improving the knowledge base.

The Technical Advisory Committee (TAC) of the CGIAR commissioned a study of training in the system just prior to the impact study being organized so it was agreed that the TAC study would form the quantitative basis of information about training in this report. Much of this chapter is drawn from information assembled and papers produced by the TAC study team (e.g. Bunting, Arajio and Herz 1985).

9.2 Magnitude and Costs

9.2.1 Aggregate indicators

Since IRRI began to provide training in 1962, more than seventeen thousand people have participated in training programs run by the centers, and approximately 3000 a year receive training currently. Many of these people are now national and international leaders who have made professional contributions to research and development of agriculture in the developing countries. Yet there were approximatley 60,000 agricultural researchers in

the developing world in 1980 (Judd, Boyce and Evenson 1984) so the centers' contribution, large as it seems, represents no more than a fraction of all professionally trained people in the developing countries.

The former participants in training provide some of the most important channels of communication between the centers and the national programs with which they cooperate, and they do much to support and promote the work of the centers. Because this is one of the principal ways centers can interact with national programs, all of the centers accept that they are both research and training institutions.

The directly accounted costs of training and conferences consume about eight percent of the core budgets of the centers. However, the total real costs, which are not precisely known, are somewhat more because the training uses staff time and the physical resources of the research programs and services of the centers, which are met from other categories. The nominal cost in 1984 was about $13.5m. Though financial stringency has tended to restrict spending of core funds on training, the volume of training has been maintained, in several centers by special projects.

9.2.2 Types of training

The chief types and means of training provided or promoted by the centers include:

(a) General and specialized courses for groups, lasting from one week to several months, often through a crop cycle, intended to acquaint participants with the methods and results of research at the centers;

(b) Individualized attachments for research workers and managers, lasting from a few weeks to two years, in which they conduct research and learn new techniques. A somewhat similar category includes postdoctoral attachments in which individuals both learn and conduct research under the general guidance of a senior center researcher;

(c) Degree-related research of up to three years, related to the thesis requirements of a degree (usually masters or PhD) at a university in a developing or other country. Centers have a marked comparative advantage in training of this sort;

(d) "In-country" training in national or regional institutions, sometimes conducted cooperatively with former participants of training at centers, whose content is similar to that of category (a) group courses at centers;

(e) workshops, conference and seminars;

(f) library, information and documentation services; and

(g) publications of many kinds.

This chapter is concerned mainly with categories (a) to (d). Because these broad categories are defined in detail in different ways at different centers, it is not possible to be completely confident in over-viewing all activities in the system as a whole, but data have been assembled to show as complete a picture as possible.

9.2.3 Origins of participants

The centers host participants in formal courses from countries in all parts of the world. This category of training includes the largest number of people, and has served more than 11,000 individuals over the years indicated in Table 9.1. The largest number have come from countries in Africa, with Asian countries providing the second largest number. It is clear that the

Table 9.1 Number of individuals from different regions participating in group courses held by CGIAR centers[a]/

Center	Years	Number of participants from: Sub-Saharan Africa	Middle East North Africa	Asia	Latin America	Industrial Countries	Average no. per yr recently
CIAT	1968-84	3	2	52	984	0	90
CIMMYT	1966-84	307	258	410	558	31	130
CIP	1978-83[b]/	415	209	772	448	6	540
IBPGR	1973-82	23	39	246	62	26	130
ICARDA	1978-83	1	244	22	0	2	40
ICRISAT	1974-82	355	4	202	13	7	90
IITA	1970-83	1905	5	74	44	51	500
ILCA	1975-83	153	0	0	0	0	110
ILRAD	1972-82[c]/	339	0	32	7	63	25
IRRI	1962-82	68	7	1678	15	12	240
ISNAR	1981-83	307	11	97	121	0	180
WARDA	1973-84	1081	0	0	0	0	120
TOTAL		4957	779	3585	2252	198	2195

Source: Data suppplied by centers to TAC.

a/ IFPRI does not run group courses.
b/ Data include participants attending courses conducted by CIP regional staff in 32 countries.
c/ Data include 45 persons who were degree candiates or post-doctoral fellows.

centers tend to draw participants from the regions in which they are located, but that most also draw some participants from other regions. IRRI and IITA has been conducting courses over a long period and hence have large totals. Relatively few participants are nationals of industrial countries.

CIAT, CIMMYT, IITA, IRRI and WARDA all have trained over 1000 participants in their group courses over the years. The more recently established centers have trained fewer in such courses. IITA has one of the largest programs of training among the centers, reflecting the continuing strong demand in Africa for the technical type of training that can be efficiently provided in group courses.

IFPRI does not run formal courses and, indeed, does not have a designated training program. Rather, the approach taken in seeking to enhance professional skills in food policy analysis in this center with its modest number of staff, is to develop close and sustained collaborative arrangements with local and regional research organizations. Recent examples of such intense interactions are its relationships with Tamil Nadu Agricultural University and the Bangladesh Institute of Development Studies.

CIP has the largest number of participants in group training in recent years, but this number is not completely comparable with those shown for the other centers because it includes all of CIP's regional training participants. This is the principal category of group training by CIP and, by 1986, group training will no longer be provided at CIP headquarters.

The total number of participants sponsored for degree-related training is much smaller than the number attending group courses or individualized

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programs at the centers, but at over 1400 is nonetheless a significant contribution (Table 9.2). While disaggregated data are not available from all centers, data for three show that 58 percent of participants were studying for master's degrees and 42 percent for PhD degrees. Thus, a conservative estimate is that the system has helped in the education of over 500 PhD holders from the developing countries. The distribution of participants across centers and regions shows that the largest group is from Asian countries and the second largest from Sub-Saharan Africa.

Among the centers, IRRI has been most active in sponsoring students for degree work, followed by IITA. Both of these centers have arrangements to send scholars to universities located close to their headquarters. Most other centers are more distant from universities and have sponsored a higher proportion of scholars for degree work in the industrial world. A proportion of degree-related scholars are nationals of industrial countries. These scholars and their sponsors continue to be active in pressing centers for training places and in seeking relevant experience at the centers in order to develop their own expertise and national capability in agricultural development, including expanding their capacity to provide staff for the centers.

Degree-related participants are, in most cases, associated with centers in order to use their research facilities and to receive guidance from scholars among the center staff who are immersed in research problems of current relevance to developing countries. Center staff are thereby much closer to such problems than are professors from industrial country universities and are more intimately involved in research than are many developing country professors.

Table 9.2 Number of individuals from different regions conducting research at CGIAR centers that was used toward advanced degree requirements. a/

Center	Years	Number of participants from: Sub-Saharan Africa	Middle East North Africa	Asia	Latin America	Industrial Countries	Average no.[b] per yr recently
CIAT	1968-84	9	0	4	130	58	25
CIMMYT	1966-82	19	18	9	26	20	5
CIP	1978-83	0	4	5	67	3	10
IBPGR	1973-82	13	12	20	5	4	10
ICARDA	1978-83	0	13	2	0	5	10
ICRISAT	1974-82	20	0	71	4	21	30
IITA	1970-83	172	0	7	2	81	65
ILCA	1975-85c/	28	0	0	0	0	15
ILRAD	1972-82c/	28	0	0	0	5	15
IRRI	1962-82	10	0	492	13	30	150
WARDA	1973-84	47	0	0	0	0	20
TOTAL		346	47	610	247	227	355

a/ In most centers, master's and PhD scholars are included

b/ Number in residence at the center during a year. Each participant typically takes 1 to 3 years to complete research activities at the center.

c/ Total number at both levels for all regions is allocated as they were distributed in 1983.

About 3500 people from developing countries have participated in individualized training programs at the centers (Table 9.3). All of the nine centers shown have some facility for individualized training. This category of participant includes many different kinds of arrangements under which researchers gain some exposure to the centers. Tourist-type visitors are excluded from these data, even those with scientific interests who spend a day or a week at a center. These number in the hundreds per year at several centers. The data in Table 9.3 are intended to reflect those whose visits are sponsored by the center and who work on a program sanctioned by the center. It is, however, rather difficult to define this category clearly.

Post-doctoral training activities are not undertaken at all the centers, according to data gathered in the course of the TAC training study. Post doctoral participation is summarized in Table 9.4. IRRI has had by far theADP largest number but the activity has also been important at CIMMYT, IITA and ICRISAT. IFPRI does not, strictly speaking, consider appointments shown here as post-doctorals but rather as research collaborators. The largest number of post-doctoral participants have come from Asian countries, with quite a few from industrial countries and a substantial number from Africa.

9.3 General Assessment

Though people trained at centers usually represent a small proportion of all professional workers in agriculture in most countries, they are warmly praised and evidently have appreciated attributes. The countries wish for more training by the centers (section 5.4), though the types of training that they desire tend to change as development proceeds. Indeed, the training offered by centers does change over the years. It is consequently difficult

Table 9.3 Number of persons from different regions participating in individual research training programs at CGIAR centers

Center	Years	Number of participants from					Average no. per yr recently
		Sub-Saharan Africa	Middle East North Africa	Asia	Latin America	Industrial countries	
CIAT	1968-84	25	1	35	1265	73	135
CIMMYT	1966-82	176	211	350	409	52	70
CIP	1978-83	16	5	35	135	9	50
IBPGR	1973-82	2	5	16	5	6	5
ICARDA	1978-83	1	48	1	0	4	10
ICRISAT	1974-82	3	5	9	2	0	15
IFPRI	1979-84	0	0	0	0	0	5
IITA	1970-83	212	1	17	6	17	25
ILCA	1975-83	44	0	0	0	21	30
IRRI	1962-82	28	6	405	14	25	100
TOTAL		507	282	868	1836	207	445

Table 9.4 Number of persons from different regions participating in post-doctoral programs at CGIAR centers

Center	Years	Number of participants from					Average no. per yr recently
		Sub-Saharan Africa	Middle East North Africa	Asia	Latin America	Industrial countries	
CIAT[a]/	1969-83	0	0	0	37	9	15
CIMMYT	1966-82	3	6	13	18	48	15
ICRISAT	1974-82	9	0	32	9	21	20
ICARDA	1978-83	0	11	0	0	10	5
IITA	1970-83	33	1	17	2	23	10
ILCA	1975-83	2	0	0	0	4	5
IRRI	1962-82	2	0	169	5	41	20
IFPRI[b]/	1975-83	14	0	51	6	0	10
ILRAD[c]/	1972-82	36	0	0	0	64	10
TOTAL		106	7	282	77	210	110

a/ Total is 38, allocated in proportion to CIAT's overall geographical distribution of trainees.
b/ Research collaborators at the professional level.
c/ Total number is 100, distributed across regions in proportion to the 1983 distribution.

for each nation to coordinate its responses to the offers of training that it receives from the different centers with which it cooperates. There is considerable demand for more higher degree training, which is costly.

In a number of countries, the scientific standards of the centers are so far ahead of those of the national agricultural knowledge system and institutions, that it is difficult for the countries to derive full benefit from the work of the centers. In other countries, only the degree training possibilities are perceived to be of real value.

Training at the centers has clearly strengthened agricultural research and the agricultural knowledge systems in many nations, and has played its part in the increases in output that many of them have realized. This is especially true where research is initiated on a commodity for the first time, as for example cassava and potato in many countries or where a country undertakes rapid expansion of a research area (see Feature).

In most cases, the centers select participants who have been nominated by governments or other employers in response to invitations from the centers. This two-stage process helps to maintain standards. Some degree-related participants are proposed by donors.

FEATURE: Researchers to Facilitate the Introduction of a New Crop

In the early 1970s Bangladesh was known by some observers as the agricultural "basket case" of the world. Massive food aid shipments were keeping the country afloat. Since then food aid has been halved, other cereals imports have been reduced by 25 percent and production of wheat, a new crop, has increased sharply. Situated on the threshold of the tropical worlds' wheat region, for a long time it was believed that wheat could not grow on a large scale in Bangladesh. But the events of 1965 to 1980 changed that perception: the area of wheat increased from less than 60,000 to over 425,000 ha and production increased to over 1.0 million tons (see Ch. 7). Training, with the assistance of CIMMYT, was a crucial part of the reason for this success.

In the middle 1960s after the first introduction of semi-dwarf wheat, senior CIMMYT staff reviewed wheat research and production in Bangladesh and recommended many changes including: (a) replenishment of seed stocks by importing varieties like Mexipak 69, and Super X from Egypt, (b) increased wheat prices, (c) appointment of a technical coordinator for the crop, (d) expansion of training, (e) initial concentration on selection rather than breeding, (f) additional research staff for off-station trials, and (g) development of seed certification. A training program for Bangladesh researchers was established with funding from the Ford Foundation, which periodically also reviewed the progress in wheat production.

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Between 1968 and 1973, five Bangladeshi researchers were trained at CIMMYT in the crop improvement areas of plant breeding, pathology and production. In the next five years, an additional eleven persons were trained, seven in crop improvement. It was agreed that, with the support from the Ford Foundation, CIMMYT would train agronomists and farm managers for Bangladesh's agricultural research system besides subject matter specialists in wheat extension agronomy, and a total of 17 persons were trained in experiment station management and 19 in production agronomy between 1968 and 1984.

The expanded wheat research program started in May 1975. By this time the breeders, production agronomists and pathologist trained at CIMMYT were working in a team. A 1979 visit of CIMMYT researchers expressed concern over the fact that there was much greater dependence on a single variety, namely Sonalika than was really safe for the country. Selection for material more resistant to leaf rust was recommended and the multidisciplinary team necessary to implement this and other recommendations was able to undertake the work.

A proposal for the establishment of a wheat research center under the Bangladesh Agricultural Research Institute (BARI) was made in 1980. In all, 38 technical officers and 34 office and field assistants were provided for in the project. A resident advisor from CIMMYT was also requested. Informal training provided through frequent visits, consultations, and review of wheat work, supplemented the wheat scientists' own initiatives and efforts. Observations made by CIMMYT scientists, Ford Foundation staff and others, highlight the intimate rapport which existed between Bangladeshi scientists and their advisors.

According to former participants, the strengths of CIMMYT's training include the team spirit, the collegial atmosphere, emphasis on learning by doing and the professional values imparted indirectly by the behavior of senior scientists-cum-trainers. This is not to belittle the contribution of substantive skill-building in various disciplines.

The weaknesses, on the other hand, include the repetitive nature of experiments, incomplete coverage of the crop cycle and the lack of theoretical rigor in the curriculum. The need for relating training content to the specific problems and resources of developing countries was also voiced by many participants. There was a feeling that the analytical skills were given less importance than technical skills. A recently returned participant from CIMMYT mentioned that, while at CIMMYT, he did everything with his own hands whereas on return, he would start ordering others around. Short term training at CIMMYT also had the drawback of disqualifying the participants from going for a longer term of training abroad. Despite these limitations, some of the people who underwent training in the initial period showed remarkable commitment to wheat research.

Examples were given by participants of how they had utilized their skills after coming back. It is to the credit of the wheat research center at BARI that, in general, it is one of the most cohesive groups having an exceptionally cordial work atmosphere. Among some 49 researchers trainees, the wheat research program has lost only about 18 percent. The economics and farming systems areas have been left relatively under-covered, although a 1978 review recommended several activities that would have helped in this area.

The CIMMYT-CIDA program provided for training of four BARI scientists a year. The trainees in farm management courses were generally from the Bangladesh Agricultural Development Corporation (BADC) which played an extraordinarily vital role in seed multiplication and distribution. An innovative feature of the seed distribution program of BADC is a project in which farmers select a particular variety of their choice and are given a kilogram of seed in the pre-sowing period. The Federal Republic of Germany has been helping BADC through providing small machines that improve the quality of seed processing. But distribution points need to be opened in more areas. Equitable and efficient seed distribution, particularly on credit, is required for small-scale farmers.

Coordination within BADC with regard to crop-oriented programs may need to be reviewed and strengthened. There has also not been much effort to provide the potentially valuable links between the wheat research programs of India and Bangladesh. CIMMYT could possibly try to facilitate more cooperation.

In any research program, mobility of officials forms an important ingredient of learning as well as management. In the past, the reimbursement of travel expenses took as long as one year. At such junctures, sundry advances from CIDA/CIMMYT staff proved extremely effective in overcoming bottlenecks with regard to the travel of wheat scientists.

The reward system needed considerable strengthening and improvement. It is creditable that, while the wheat program received special awards in the earlier years from the government and from private voluntary organizations, there were not many staff members who had been given accelerated increments.

This is one area which continues to require attention by both BARI management and the public service authorities.

A National Wheat Research Center was established in 1982 and is now on its way to becoming a self-contained research nucleus focused on the site alloted for the purpose about ten years ago in N.W. Bangladesh. The role of wheat in the food basket of the next century in the country will be shaped from here.

Leadership is an important requirement in order that any research program take off. In Bangladesh, CIMMYT training played a crucial role in developing that leadership in the wheat program. The man identified as the leader of the wheat program was considered "too young" by the promotion committee in 1974 and was successfully promoted to principal scientific officer only after Dr. Borlaug of CIMMYT aware of his potential, wrote to the Secretary of Agriculture. The frequent visits, range of skills in which training was offered and team spirit engendered by the training program have been important in helping Bangladesh build an effective wheat research team.

END FEATURE

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One consequence of the selection process has been the small proportion of female particpants in center training and fellowship programs. Although there are many factors influencing the situation, not all of them lie beyond the centers themselves. While it has not been possible to determine the exact percentage for each center, the eight percent female trainees out of the total number participating in IRRI programs between 1962 and 1981 would seem typical. The centers, in strict terms, have been engaged primarily in the development of manpower rather than human resources per se.

Some participants, initially in the transition to the new and different environment of a center, find it difficult and startling, but these reactions are soon overcome. The principal continuing difficulties are those of language. English is perhaps the principal language of agricultural science internationally and it is of most of the centers, but increasingly, centers are either providing some training in other languages or providing some language training to participants who work in other languages.

By their own reports and those to whom they report in national organizations, the effects on the participants of training at the centers are profound. The training experience increases knowledge and skills, employment of intellectual and physical labor, motivation, determination, purpose and confidence. Continuing contact with the center afterwards offsets isolation and helps participants to feel that they are valued citizens of the professional world.

The subsequent careers of participants suggest that, through these effects, most are able to serve research and development in their nations more effectively, even though many are promoted out of active research and some

move to commodities and disciplines different from those in which they were trained at a center.

Centers undertake training to advance their cooperative programs, to build national capability in research and other sectors of national agricultural knowledge systems, and to identify suitable candidates for their own staff and those of other advanced institutions.

Each center has links in training with many countries (up to 80 countries in some cases) and each of the countries contacted in the TAC training study has links with an average of about seven centers, which approach it separately, even if they are offering training in similar fields. This can lead to difficulties; for example, in studies of farming systems research methods. The centers are aware of these problems and have taken steps to lessen them. One recent concrete action was an agreement by all CGIAR centers operating farming systems training activities in Africa to keep one another informed of their respective courses and to carry out joint activities wherever possible.

Since the centers cannot meet all the perceived needs of the nations for training on topics in which they have comparative advantage, they promote "in-country" training. While these have some advantages, they also tend to dilute the benefits of being immersed in the atmosphere of an international center, which is available only at the center itself.

Centers simply cannot meet all expectations in respect of opportunities for thesis research for higher degrees - in which they have outstanding

comparative advantage. To do more in this direction they will need more staff, more accommodation and more money.

9.4 Advantages of Center Training

Since centers (unlike most other kinds of training institutions, including universities) are able to see their training participants as future continuing cooperators in research and dissemination, they do all they can to keep in touch with and to support them, and so increase the return on their investment of funds and effort in training. One center has set up a formal association of alumni; all send much of their published material to as many former participants as they can reach. Participants may be invited back to a center for workshops or to help in training others. These contacts are often very valuable to the former participants, not only for the information they convey but also because they imply continuing recognition and support. This helps to offset the sense of professional isolation, and the risk of obsolescence that is so great in the small and fragmented agricultural knowledge communities of many developing countries, particularly where foreign exchange for books, journals and travel is scarce. The annual report of a center may be one of the more important sources of information that a participant has. Indeed, this continuing contact and support may be one of the significant reasons why the participants have become a distinct and leading group in so many countries.

The leaders of national systems value training at the centers for a wide range of reasons, some of which were also given by participants themselves. Of course, most countries wish for all the training they can get, particularly if the costs can be met from external sources, but cost is probably not the

primary consideration. It is not always easy for a hard-pressed service to release staff for training, even if there are no external costs, or to guarantee participants jobs when they return.

Training by the centers has certain unique characteristics. It provides a continuing link, through former participants, with the centers and their work, and thus with the continuing advances of agricultural science generally. It improves the quality and performance of the participants, except in those rare cases where people may have been trained beyond the capacity of their nations to use their training. In these ways training by the centers has improved national agricultural research capabilities in many developing countries. It has also had effects on development, which are now considered.

Some nations have used training at the centers to strengthen the links between the different parts of the national agricultural knowledge system. When Indonesia began to cooperate with IRRI, research workers, extension leaders and district managers were sent to IRRI together. Before, they had not known or cooperated with each other. "They returned from IRRI hand in hand." Evidently, the authorities felt a need for research-related training in other areas of the agricultural knowledge system besides in research itself. Moreover, this soon led to "in-country" rice production and improvement courses in Indonesia, assisted by IRRI. The output of rice (supported by appropriate actions outside the domain of knowledge) began to increase; and it seems that the unit cost of the output decreased. Indonesia is today self-sufficient in rice.

The former participants encountered in the case studies were generally impressive individuals. Of course, they are a highly selected group, but it

became clear that the effects of training on most participants are profound. Many of the participants explained that the experience had changed them as people as well as professionals. They spoke not only of advances in knowledge and technical skills, but also of dedication to both intellectual and physical work, motivation, determination, purpose and confidence. Many, particularly those who had attended production courses, had become trainers themselves, and had organized such courses in their own countries.

These assessments of the effects of training at a center were consistently confirmed by supervisors in most of the nations - often using virtually identical language. A few, while recognizing these general effects, suggested that work at a center could accustom people to techniques and equipment that could not be used or were not available when they returned home, but such remarks were sometimes colored by experiences with students who had followed higher-degree courses in universities in industrial countries. In the broader perspective, the relative exclusion of women professionals from participation in center training and, in turn, from emerging agricultural knowledge systems can have only a deleterious effect, perhaps especially though not solely where women's participation in food farming and marketing are highest.

The center participants include many leaders in agricultural science and development, clearly different, in many countries, from the majority of professional workers in those fields. Of course, many developing countries have produced distinguished leaders in other ways but, even in those cases, the CGIAR participants significantly add to their human resources for agricultural science and development.

Many reasons were given for these effects (section 5.4). One of the most general was that much of the experience was practical, particularly in production and breeding courses. To work with a crop in the field from sowing to post-harvest operations, or to learn a specialized technique in the field or laboratory, turns theoretical knowledge, acquired from reading and listening (from "the study of agricultural science as a branch of literature" as one senior observer remarked) into practical competence and understanding. Such an experience provides a basis for genuine confidence; and it makes for far more effective research workers. Few research workers seem able to do effective research on a crop unless they also know how to grow it themselves.

9.5 Changes in Types of Training

Given the data at hand it is not possible to quantify all the trends that have occurred over time in the training offered by the centers but several are evident. One is the trend toward a lower proportion of training in production courses in favor of a higher proportion of training in research methods. A second is the trend toward a greater proportion of total training activities outside the headquarters of the center, or so called "in country" training.

Figure 9.1 shows the increases that have occurred in number of in-country training participants of just one center over the past several years. This kind of training with cooperation between national programs and the centers is, of course, essential and must clearly be encouraged, until a nation's agricultural knowledge system is strong enough to manage training for itself. Indeed, it must be an objective of the centers to hasten the day when in-country training becomes in-country business. But in-country training must

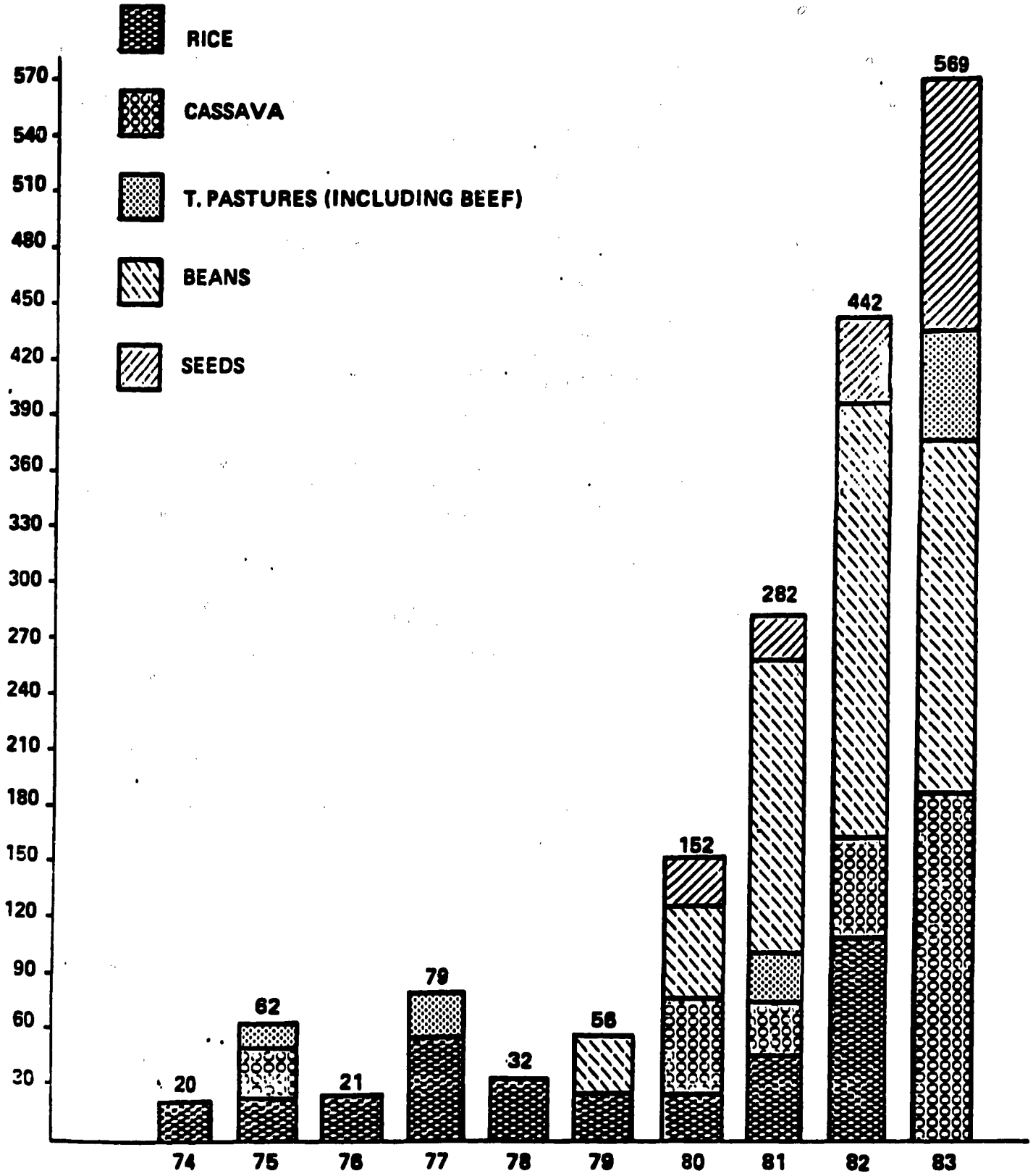

Figure 9.1 NUMBER OF PARTICIPANTS OF IN-COUNTRY TRAINING COURSES ASSISTED BY CIAT 1974 — 1983.

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often dilute some of the special effects of training at a center that were considered above. The "call system" (by which trainers from a center respond to a call from a country to visit training participants at critical stages of the crop cycle) and the systematic training of trainers to create domestic capacity are means of offsetting this potential loss. Some centers support in-country training by bringing the in-country trainers to headquarters from time to time as visiting scientists or as trainers. All support the in-country trainers with senior professional staff.

The contributions of the centers to degree-related training have been modest, but the centers are potentially able to offer unique opportunities for advanced training, on topics important for developing countries, and in appropriate environments, and the graduate student participants have made valuable contributions to centers' programs. The centers are held back from doing more in this area by lack of funds and by the constrained senior staff time required to provide adequate supervision, particularly when theses have to be written.

They cannot fairly relinquish their tasks to their university partners, unless these partners are involved in the supervision of the work as practical collaborators in the centers. But for many academics, and for some centers, this route offers difficulties. In some centers, many of the scientific staff are dedicated to their research responsibilities, and not all of them see the supervision of higher degree candidates as a natural extension of these tasks. This is a question of attitudes, from the senior management down, and it is unlikely to be resolved solely by including academic supervisory tasks as part of the contractual responsibilities of center scientists. If the centers are to provide more degree-related training, as some believe they should,

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additional posts, additional accommodation and additional funds will be needed. In some cases it may be useful to appoint experienced academics, where possible from the cooperating universities, as sabbatical workers whose duties include academic supervision, and some appointments have indeed had this character in the past. Post-doctoral researchers may also assume part of the task, as they do at ILRAD. The centers are not universities, but they need some characteristics of university institutions if higher degree work is to be increased.

In many developing countries there are substantial plans to support higher education, but few of these plans take account of the possible contribution of the centers. Some of the funds to be applied come from sources earmarked for bilateral technical cooperation in education and training, rather than from sources intended for multilateral support for agricultural research. It should be possible to resolve this emerging problem - particularly if the recipient countries themselves insist that the centers be used for higher degree training in appropriate cases.

9.6 Coda

* The CGIAR system recognizes the need for developing countries to improve their own capacities to conduct research and is engaged in many different efforts to improve that capacity.

* More than seventeen thousand people have been trained at the centers.

* Former participants in training provide some of the most important channels of communication between the centers and the national programs.

* The direct costs of training and conferences to enhance human capital consume about eight percent of the core budgets.

* CIAT, CIMMYT, IITA, IRRI and WARDA all have trained over 1000 participants in their formal courses. IITA has one of the largest programs for such training, reflecting the continuing strong demand for technical training.

* The system has helped in the education of about 500 PhD holders and about 900 master's holders, but not all senior scientific staff of centers see the supervision of higher degree candidates as part of their responsibilities.

* About 3500 people from developing countries have participated in individualized training programs at the centers.

* People trained at centers are generally warmly praised by their supervisors and evidently have special value to their countries. The countries wish for more training by the centers though the types of training they desire tend to change as development proceeds. There is considerable demand for more higher degree training.

* Training at the centers has clearly strengthened agricultural research and the agricultural knowledge systems in many nations, and has played its part in the increases in output that many of them have helped to realize.

* The training experience increases knowledge and skills, employment of intellectual and physical labor, motivation, determination, purpose and confidence.

* The relative exclusion of women professionals from participation in center training and, in turn, from emerging agricultural knowledge systems can have only a deleterious effect, perhaps especially though not solely where woman's participation in food farming and marketing are highest.

* Since the centers cannot meet all the perceived needs, they promote "in-country" training.

* Centers cannot meet all expectations for thesis research for higher degrees. To do more in this direction they will need more staff, more accommodation and more money.

* Countries value training at the centers for a wide range of reasons. Training by the centers has certain unique characteristics. It provides a continuing link, through former participants, with the centers and their work. It improves the performance of the participants and the quality of their work.

* There is a trend toward a lower proportion of training in production courses in favor of a higher proportion of training in research methods. There is also a trend toward a greater proportion of total training activities outside the headquarters of the center, so called "in country" training.

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10 NATIONAL RESEARCH CAPACITY

10.1 Introduction

The growth of national agricultural research systems and international research centers is a mutually reinforcing process. The international centers were built on scientific knowledge generated by national systems in industrial and developing countries. They assembled germplasm collections from national programs and others, and systematically built networks upon them, becoming stronger as the national programs which participated in them produced better materials. They hired research staff from universities and national programs of industrial and developing countries. The national programs, in turn, have gained much from the centers. This is to the benefit of the centers, the farmers and others. International centers cannot have much impact on farming unless there are researchers to do adaptive work at the national level and extension workers to exchange ideas with the farmers. The national systems develop technology for farmers using materials supplied in part through the international networks, together with centers' and others', methods and ideas. Without the capacity to adapt technical components to local conditions, there would be severe constraints to using center-developed technology because it would fit relatively few situations well.

The aggregate growth of national research systems over the past quarter century has been rapid, but some important activities cannot readily be carried out by some national institutions, and many national programs still have important weaknesses. It is in some of these areas that the international centers have played, and will continue to play, an important role. The international testing and movement of germplasm can be handled more

effectively by an international organization than a national research program. Establishing and supporting international networks of research workers is another type of activity that may often be done best by an international center. Many developing countries seemingly are still not investing sufficiently in agricultural research. Some systems lack sufficient human resources to carry out effective research programs and endure institutional inefficiencies that prevent them from making good use of available resources.

There are three principal ways by which the international agricultural research centers can influence national research capacity. First, is by the education of policy makers and the public at large on the productivity and the importance of research, including studies of the returns to research and the benefits generated by research in other countries. Second are projects to build national research institutions. These include special projects such as IRRI's long-term work in assisting in the development of the Bangladesh Rice Research Institute and CIP's work to assist PRECODEPA in Central America, as well as most of the work of ISNAR. Third are the regular services which the centers provide to the national systems, including collaborative research, training, storage and distribution of germplasm, research methods, the findings of basic research, bibliographic services, publications, conferences and so on.

All the centers have committed substantial resources to assisting in the development of national research institutions, both in direct and indirect ways. The need for such development was considered to be so important that, in 1980, the CGIAR established ISNAR. Its constitution states that ISNAR's "ultimate goal is to enable developing countries to plan, organize, manage and execute research more effectively." This chapter is devoted to discussing the

contribution of the CGIAR system to building national research capacity, but many of the support services of the centers that are discussed in other chapters are not repeated here.

The impacts on the national research systems fall into three major categories: (a) impact on aggregate national budgets for research: (b) impact on the allocation of research resources by commodity, project and discipline: and (c) impact on the organization of the institutions for research and technology transfer. The latter category includes such things as changes in institutional structure, improved research planning and management, new research methods, and improved linkages among research, education and extension institutions, both domestically and abroad.

10.2 Financing National Research

The existence of the CGIAR has affected the level of finance available for national agricultural research by its demonstration effect as well as by its effect on the expectations of national decision makers. The publicity surrounding the green revolution raised the expectations of decision makers in many developing countries about the potential benefits from agricultural research (chapter 3). Economic analyses of the consequences of new technology, including impacts on income distribution and nutrition, helped to quantify the returns to research and to generate support for national agricultural research. Collaboration with the centers raised the productivity of research and helped governments to see that there could be high returns to research in the future. The publicity and productivity effects not only influenced national research systems, but also helped to persuade foreign donors that agricultural research was a productive investment.

Some observers have taken an opposite position - suggesting that a rational national program would neglect domestic research capacity by "free-riding" on the centers, especially when there is one located within the boundary. There have also been suggestions that the international centers attracted financial resources from donors that may otherwise have been invested directly in the national systems.

Evidence collected in the country case studies generally supports the former view. Scientists who were active in Asian national research systems in the 1960s say that the green revolution convinced many national leaders that research could really accomplish something significant. The Ford Foundation representative in Pakistan planted CIMMYT varieties on the fields of President Ayub and several of his top advisors. The yields on those fields assisted in bringing home to the government that wheat research would be a good investment. Senior officials in Bangladesh (then East Pakistan) travelled on an IRRI-sponsored tour of the Philippines and Japan that effectively demonstrated the potential of IR8 and similar varieties, and of agricultural research more generally.

The Rockefeller and Ford Foundations have long been concerned with world food problems, and they took strong leads in supporting agricultural research addressed to their solution. USAID started to support agricultural research in the late 1960s, partly in response to public concerns about the food crises of Asia. The early successes of the centers clearly influenced USAID's decision to invest in national research. Over the past three decades, several donors responded to the food crises in various parts of the developing world

with, inter alia, additional support for research. The performance of the food production sectors of Asia has clearly justified that support.

As yet, there has been much less evidence of research benefit in Africa, where the investments were made later and the base of commodity-specific knowledge was generally lower but, as shown in chapter 3 there has been significant growth in domestic systems. IITA became involved in root crops improvement in Cameroon in 1977. This involvement has led to a greater appreciation on the part of government of the value of research and development and has resulted in about a five-fold increase in government expenditure on root crops improved between 1978 and 1984. The Cameroon National Root Crop Improvement Program has been strengthened to the point that it is now self-supporting.

Data on the stability of funding of research in national systems are even more sparse than they are for recent levels of funding. An interesting hypothesis that could be addressed at some data-richer stage is that stability of funding for the centers has positively influenced stability of funding in national research systems. Authorities from the developing countries have observed in this study that erratic funding has produced national research that is perfunctory, half-hearted and replete with half-completed and abandoned projects, and may have been more damaging to research productivity than the inadequacy of the general level of funding.

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10.3 Research Priorities

10.3.1 Commodity

A key issue for any research system is the allocation of research resources between different commodities, disciplines, institutions and projects. Allocation between different commodities has received much attention by analysts generally and, within the CGIAR, by TAC in particular. The centers were in part a response to a perception that too little research was being done on food production and consumption. Their activities have, it seems, indeed induced more national research on the key food crops (see section 10.9 below).

The inducement effect is clearest where counterpart research programs did not exist prior to center involvement. For example, many countries had no organized research program on cassava or other root and tuber crops until they came into contact with IITA and CIAT. A total of 23 national root and tuber crops improvement programs have been developed in Africa since 1971, stimulated by IITA's work on cassava, yams, sweet potatoes, and cocoyam. Table 10.1 shows some aspects of CIAT's participation in a number of new cassava research programs. Only India had a national cassava research program before the centers' programs were established. Wheat research programs in the Philippines, Thailand and Burma have been analogously stimulated by CIMMYT's tropical wheat research.

Collaboration has led to increases in the size of existing programs in many countries. Table 10.2 shows that, in Bangladesh, rice research investment was considerably smaller than that for jute research during the early 1960s. By the 1970s, Bangladesh policy makers were investing much more

Table 10.1 Some links between national cassava research activities and CIAT

	CIAT trainees	Receiving genetic material from CIAT[a]/	CIAT lines released or grown	Visits by CIAT staff since 1977
Thailand	24	S	Yes	18
Indonesia	12	S	No	8
Philippines	11	S	Yes	18
Malaysia	14	S	No	10
China	0	S	No	2
India	5	S	No	11
Brazil	94	S	Unknown	34
Paraguay	3	S	No	6
Bolivia	5	No	No	6
Peru	10	S	No	7
Ecuador	12	No	Yes	18
Colombia	86	E	Yes	NA
Venezuela	14	No	Yes	2
Panama	7	M	No	6
Costa Rica	9	Np	Yes	12
Mexico	31	SM	Yes	27
Haiti	4	No	Yes	6
Dominican Republic	20	No	Unknown	17
Cuba	12	S	Yes	14
Guyana	4	No	No	1

a/ M = Meristems, S = Seeds, E = Stakes.

in rice research, and a few donors enabled the country to obtain the foreign exchange needed to build its capacity for rice research.

The analysis of commodity research expenditures for 25 developing countries described in section 10.9 below shows that, during the 1970s, there was a strong positive association of national commodity research expenditures with research expenditures on the same commodities by the centers. That is, national research investments increased more rapidly for commodities being researched by CGIAR centers than for "non-center" commodities.

Young national systems often respond strongly to the activities of the centers, rapidly building research capacity in a particular area, perhaps leaving behind their capacity in other crops or ecologies. For example, Syria's research expanded about three-fold between 1978, when it handled 144 projects, and 1984 when it had 343 projects (El-Akhrass 1985, p.18). Research on field crops corresponding to ICARDA's activities made up about 42 percent of the projects in 1978, while by 1984 it made up 73 percent.

But with development, national priorities are reasserted. The experience of Bangladesh again is instructive. As noted, Bangladesh greatly expanded its rice research activities between 1965 and 1980. During the late 1970s, national authorities and donors became aware that technological development for other crops was falling behind, and a major effort was made to strengthen another institution, the Bangladesh Agricultural Research Institute, with responsibilities for research on other major food crops. Expenditures on other food crops far exceeded those on rice by 1980 (Table 10.2). It could be argued that IRRI's influence initially "distorted" the national priorities in this case. Alternatively, however, the argument can be

Table 10.2 Allocation of agricultural research expenditures in Bangladesh (Tk M current)

Crop/ Institution	1950-[a] 1960	1960-[a] 1965	1967	1974	1979	1980
Rice	.2	.3	1	7	28	40
Other food crops	.2	.2	n.a.	12	77	129
Jute	.2	.5	2	2	10	11
Tea	0	n.a.	n.a.	2	6	5
Sugarcane	n.a.	.1	.1	4.5	10	14
BARC	0	0	0	n.a.	5	11
Livestock	n.a.	.6	.3	2.8	n.a.	n.a.

a/ Annual average.

Source: Pray and Ahmed (1984).

made that the successfully functioning rice research institute was a strong stimulus for the establishment of the needed national capacity for research on other crops.

Some cases have been cited as examples of centers "crowding out" local research. In particular, countries that host centers face particular challenges in determining appropriate domestic institutional responses. IRRI research appears to have been a partial substitute for national rice research in the Philippines, in that investment in rice research would probably have increased more rapidly in the absence of IRRI. The Philippine Council of Agricultural and Resources Research and Development (PCARRD) had, until recently, decided that rice was a priority II crop and, as such, allocated it fewer resources than for priority I crops such as maize. The University of the Philippines Institute for Plant Breeding, the major institution for crop improvement, until recently undertook no rice research, and the University's Department of Agronomy has done only a little. The expressed view of the leadership of the Philippine Ministry of Agriculture is that virtually all of the rice research that is required is available from IRRI. Two experienced Philippine rice breeders work for IITA and IRRI. The net effect is a rice breeding program at the University of the Philippines that is probably weaker than it was in 1970, but the presence of IRRI provides a total rice research effort applicable to the Philippines much larger than it would be in its absence.

Rice research in Colombia has been cited as another example of centers replacing national programs (Trigo, Piniero, and Sabato 1983). The evidence here is not so clear, however. The share of crop research resources going to rice increased from five percent in 1964 to nine percent in 1969, and

remained constant at that level to 1983. There appears to have been a substantial shift in research priorities in recent years from irrigated lowland rice to upland rice. There is also evidence that the quality of some of the rice research program may have declined due to the departure of the most experienced rice breeders to the centers.

The pull of research resources toward food crops which the centers have stimulated seems generally to be a movement toward a more efficient allocation of resources, especially because food crops were so neglected by colonial governments. Some of the specific commodity programs instituted with center stimulation have attracted comment because they absorb significant research resources on commodities which make up a small share of the value of output. For example, Table 10.3 shows the increase in researchers on potatoes in the PRECODEPA countries. The tropical wheat research programs in the Philippines and Thailand, and the maize research program in Bangladesh are other examples.

Clearly, there are cases where the centers have effectively encouraged countries to increase their research on food crops. It is useful to remember, however, that there are a number of large national research systems and some small ones in which research by the centers has apparently had very little effect on research priorities. For example, in Brazil there has been a gradual shift of resources toward export crops. On balance, the degree of induced distortion, for the developing countries as a whole, has probably been worth whatever negative effects it might have had because of the stimulation it has given to entire national systems.

Table 10.3 Personnel of national potato programs before PRECODEPA and at present

Country	1977/78			1983/84		
	Full	Part	Total	Full	Part	Total
Mexico	2	2	4	8	10	18
Guatemala	2	2	4	11	20	31
Honduras	1		1	3	8	11
Costa Rica	1		1	6	3	9
Panama	1	1	2	4	5	9
Dominican Republic	2		2	12	5	17
	9	5	14	44	51	95

Note: All salaries are financed entirely from the respective national budgets.

Source: CIP (1984)

10.3.2 Research priorities within commodity programs

The examples of the centers and their specific successes have influenced the structure and goals of many national commodity programs, some in relatively subtle ways, others more overtly. Even before IRRI was established, some rice research programs of Asia had absorbed the lessons from Japan, Taiwan, and Korea that fertilizer-responsive varieties could raise yields. Under the auspices of the FAO, they started the Japonica-Indica crossing program in 1954, with the aim of developing varieties responsive to fertilizer. The production of semi-dwarf rice varieties such as IR8 shifted national researchers' attention away from Japonica-Indica crosses during the 1960s. The semi-dwarfs were tested under higher fertility levels and fertilizer responsiveness was adopted by some breeders as a breeding objective. Indian authorities report that there was a shift of resources from unirrigated to irrigated rice research. After IRRI started to screen nurseries without insecticide protection, many national programs followed suit. The national rice research program in the Philippines also started to breed semi-dwarf varieties for irrigated conditions, but soon decided to let IRRI work on lowland irrigated rice while it concentrated on upland rice.

CIMMYT's emphasis on breeding maize varieties rather than hybrids had a significant impact on many maize research programs in Latin America and Asia. For example, the Burmese maize breeders had concentrated unsuccessfully on hybrids until they started working with CIMMYT. Now they are directing their breeding efforts almost entirely to the production of composites rather than hybrids.

In other cases there were major changes in many parts of the research program. Research on potatoes in Bangladesh changed dramatically. Instead of

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selecting only from the best-yielding Dutch varieties, the program started selecting from the collection of local varieties and tropical varieties from CIP. Completely new research programs, including diffused light storage, true potato seed and a clean seed production program, were also added.

10.3.3 Solving farmers' problems

Perhaps the most important impact of the centers on research priorities has been the orientation of researchers toward solving farmers' problems -- oftentimes under the banner of farming systems research (see chapter 16). This shift of research efforts is probably impossible to quantify, but national research and administrative people who have worked with the system over a lengthy period persistently point to this as one of the most important contributions of the centers. The researchers in the centers provide prestigious role models for national research workers which may often be for the good. The centers provide reinforcement and rewards for practical work by their national partners in the form of attendance at conferences and publications of the results of applied research. The training programs at the centers also stress applied research in the field. To quote the then head of EMBRAPA: in the past "most of the research in Brazil ... was not oriented to the farmers' problems...This [the idea of working on farmers' problems], in my opinion, is much more important than the cultivars because...you are teaching us how to fish instead of giving us the fish." (Alves 1984, p. 123).

The Nile Valley project of Egypt and Sudan in which ICARDA is centrally involved is a good example of encouraging national scientists to work on farmers' problems in farmers' fields. This effort, aimed at testing technology to increase yields of faba beans on farmers' fields, has provided an opportunity for research workers from the two countries to conduct field

research under farmers' conditions, to interact with each other and with international scientists.

The fact that centers have such little direct contact with extension services means that any desirable influences on research systems are not readily replicated in extension or in the linkages between research and extension systems which, in many countries (and especially in Africa), remain tenuous and ineffectual.

10.4 Institutional Structure

The centers have been encouraging national research organizations to use their model of interdisciplinary teams working on the practical problems of farmers since they were established, and have had considerable success in popularizing the model. However, the time and effort they devoted directly to institution building was judged to be insufficient for building national research programs at the necessary rate, and ISNAR was established to focus specifically on that need. Thus, the centers have had informal as well as more formal influences on the institutional structure of national programs.

10.4.1 The centers as models

A number of national institutions have used the structure of the centers in designing their own activities. EMBRAPA, the Brazilian agricultural research corporation, established a series of commodity institutes organized in multidisciplinary teams as the basic structure for its new national agricultural research system. This structure was adopted on the basis of what Brazilian scientist had read about the centers and seen in visits to them. Bangladesh and Indonesia have built rice research institutes modeled on IRRI

with the assistance of IRRI personnel stationed in the countries. ICTA in Guatemala was organized following the farming systems research model developed by CIMMYT and others. In the case of several crops where little had previously been done - such as cassava and potatoes in many countries - the centers helped bring scattered researchers together into structured interaction for the first time.

IITA has influenced considerably the organization and management of agricultural research in Africa. The multidisciplinary approach of IITA has been adopted in many national research programs in Africa, particularly those in Cameroon and Nigeria. Farming systems research is, in Nigeria, an innovation which took its roots from the IITA Farming Systems Program. This has influenced the organization of research in all the national agricultural research institutes (Okoro and Onuoha, 1985, p.75), and as well, Nigerian research institutes now organize regular in-house reviews.

In addition to countries which copied entire commodity research programs, many have imitated parts of commodity programs. An example of this is the Indonesian Genetic Evaluation and Utilization program (GEU) that was established in 1975. It was formed in response to the need to coordinate rice breeding activities in order to respond better to outbreaks of brown planthopper. It took both the name and the institutional structure of IRRI's GEU program.

In contrast to the organization of a single commodity research program, ISNAR was set up to help improve the working of national research systems as a whole. ISNAR assists countries in the identification of needed changes and in promoting the needed changes by providing necessary information for decision

making, pointing to opportunities, helping to design alternatives, and helping to lower the costs of institutional change by facilitating donor support of the process of change.

ISNAR has recommended institutional and organizational change in 12 out of the 18 countries where its review and planning missions have been completed. Since it has tried to meet the specific needs of those countries, the proposals suggested have varied widely. New organizations have been proposed to improve control over resources and program matters, to facilitate more effective management of available resources, and to improve interactions with policy-making bodies in the Dominican Republic, Costa Rica, Kenya, Ivory Coast, Guyana and Papua New Guinea. ISNAR advised Sri Lanka and Malawi that they could improve their resource allocation and program coordination through the creation of research councils or their equivalent. Madagascar and Rwanda were advised that they could generate improved relations with client groups and increased accountability of research activities through new governance mechanisms for existing institutions. Changed internal organizations to improve management possibilities and the more effective use of resources constituted the core of proposals in Fiji and Morocco, and have been part of the broader institutional recommendations in the Dominican Republic, Rwanda and Madagascar. Reduction in the number of stations and rationalization of research station networks has been proposed as a way of improving the use of available resources and the effectiveness of research efforts in Madagascar, Fiji, Western Samoa, Rwanda, and Morocco.

Feature: The Dominican Republic experience

The experience of the Dominican Republic is an example of ISNAR's successful assistance to a system in the process of institutional change. ISNAR involvement in the Dominican Republic started in 1982 when the Secretary of Agriculture invited ISNAR to organize a mission to review the government research system. A team of six people visited the Dominican Republic in early 1984. They worked with a team of local counterparts to develop a proposal to create a new semi-autonomous agricultural research institute in place of the research organizations that were under the Ministry of Agriculture at the time. This new institution would have the power to promote people on the basis of merit, and the flexibility to use its budget for effective, high-priority projects. This would increase the productivity of the system by increasing the motivation of research staff and providing the more productive research workers with more resources.

The next step was to develop a proposal that was acceptable to most interested parties in the agricultural sector. Three areas of action were involved: first, the proposal had to be accepted by the research system and the Secretary of Agriculture; second, because of the high rate of turnover in top levels of the research system, a process of information sharing was required to obtain the commitment of the newcomers: finally, as discussion progressed, new interest groups such as universities, extension organizations and donor agencies had to be involved. These tasks were carried out by the local working group, with ISNAR participation through periodic visits to provide advice on specific issues. As the decision to implement the new

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institution seemed imminent, ISNAR, at the request of the Secretary of Agriculture, placed a permanent consultant in the country to work full time with the working group.

The last step was to convince the legislature (a) that research was a valid part of the solution to the food problems facing the country and (b) that the creation of the new organization was the appropriate means of achieving an effective research organization. Two instruments were used to work with the legislature. The working group and other officials from the Ministry of Agriculture contacted lawmakers on an individual basis to brief them on the nature and objectives of the new research institute. The second instrument was a national workshop to discuss the pros and cons of the initiative to create the new institute. The participants included the agricultural committees of the House of Representatives and the Senate, the present and several past heads of research and extension and other influential people connected with the agricultural sector. The workshop relied heavily on case studies constructed so as to highlight the problems of the present structure of agricultural research and the reasons why the new organization should be more effective. ISNAR helped to organize the workshop and provided materials in the form of case studies, and members of the original missions participated as resource persons.

The workshop proved to be highly successful. The result was the tacit support of the agricultural committees of both the House and Senate, and an agreement to the modifications that should be made in the proposal sent by the President to Congress.

Implementation of the above proposals has followed a different pattern in each case. Implementation is proceeding with full ISNAR participation in several countries: e.g., the Dominican Republic, Kenya, Fiji, Madagascar, and Rwanda. In others the proposals have been accepted and are being implemented essentially through local initiative with little or no involvement on the part of ISNAR: Papua New Guinea, Western Samoa, and Guyana. Finally, there are one or two where no significant action is taking place, for example, Costa Rica.

The extent of implementation is in part due to the timing of the original missions and in part due to the particular characteristics of the political and administrative processes of the countries involved.

10.4.2 Institutions for germplasm work

The IBPGR's basic function is to promote and coordinate an international network of genetic resource centers to further the collection, conservation, documentation, evaluation and use of plant germplasm and to increase the diversity of germplasm available to plant breeders (chapter 12). IBPGR has been responsible for the development of new national genetic conservation programs in about 50 countries and the development of national genetic resources committees in 25 countries. It has assisted national programs to develop their germplasm collection through grants for collection of materials and for storage facilities, training in the collection, characterization and preservation of genetic materials, conferences on the latest methods of preserving germplasm, and data banks on germplasm availability. This assistance has been channeled to national institutions and has served to strengthen their capacities to carry out such work.

10.5 Research Planning and Management

10.5.1 ISNAR

The objective of ISNAR's management training activities is to strengthen the managerial capabilities of agricultural research officials. More than 130 individuals, most from Africa, have participated in research management training programs. ISNAR has also undertaken in-depth surveys of management training needs in Cameroon, Sudan and Zimbabwe and will use the results of those surveys to develop a better focus for training and case studies for further courses.

In response to problems that came up in many of its country reviews, ISNAR has devoted considerable attention to developing professional organization and training plans for several national research programs. ISNAR worked in Kenya with the National Council of Science and Technology and the Ministry of Agriculture, to identify the characteristics of current human resources in agricultural research. This analysis led to a national staff development plan for agricultural research and to a plan to strengthen the Faculty of Agriculture at the University of Nairobi. The Service has cooperated with the Kenyan authorities in the formulation of both plans. ISNAR has provided staff inputs in Thailand to an interagency commission investigating conditions of service for personnel in the Department of Agriculture. The task of this commission is to recommend procedural changes that will encourage larger numbers of Department personnel to serve at research centers outside Bangkok. On the basis of the ISNAR work, the

commission has moved to explore revised recruitment standards and new career paths for Department personnel.

ISNAR has seemingly been cautious in collecting or making data available for discussion in relation to strengthening national research and extension institutions' capacity to reach and serve women farmers. In a number of countries with which ISNAR has been working, women are major food producers in their own right (e.g., Kenya and Papua New Guinea) or form a significant proportion of agricultural research and extension personnel (e.g., Thailand). Both cases may pose special problems of human capital enhancement and require attention in proposals for structural reorganization and planning reforms.

10.5.2 ILCA's role in providing data processing

One of ILCA's more important products to date has been the analytical services that it provides to national agencies which have large data bases on animal production, but lack the human skills or computers to appraise such data. National researchers analyze the data at ILCA with the assistance of ILCA staff. The results of these analyses allow national agencies to make informed decisions about the continuation, enlargement or reorientation of their livestock development programs. The results have also been used to assist in the preparation of livestock projects funded by major donors and lenders such as the World Bank.

The need for this kind of information is clear: "Livestock numbers, yields and, a fortiori, management practices, in traditional herds are usually shrouded in even denser veils of ignorance (and, worse, of self-confident assertion) than apply to smallholder crops data. Improvement upon the scandal of agricultural and food statistics in most of Sub-Saharan Africa is a

necessary, and inexpensive, precondition for significant policy improvement and therefore for agricultural research design..." (Lipton 1984, p.30).

10.5.3 On-farm trials and research priorities

On-farm research programs have been promoted by the centers and others and are being used by national researchers as an input into the research planning process. One of these systems is used at ICTA in Guatemala where on-farm research dominates the whole research system. Farming systems research is viewed favorably in Panama, and in several E. African countries where it has had considerable impact in influencing research styles and orientation (chapter 16). There are also examples of much less formal types of interaction between farmers, plant breeders and social science staff, helping to set new priorities. One example relates to the work of CIMMYT staff in N. India. The Pantnagar University maize research program integrated farmer surveys and on-farm trials into its work. This led to revision of the extension recommendations on pesticide and fertilizer applications. The blanket recommendation that farmers spray thiodan to prevent stem borers was withdrawn and the recommendation for N, P, and K was reduced from 80:60:40 kg/ha to 80:0:0 kg/ha. Research priorities were changed considerably. Research was increased on appropriate plant populations, and on leaf spot. More use was made of local germplasm. Concentrated research activity was shifted from Pantnagar, which was atypical of the major maize growing regions, to Bulandshalkur in the middle of the U.P. corn belt (Biggs 1983).

The survey of yields of deep water rice by personnel of the Bangladesh Rice Research Institute Economics, Farming Systems and Deep Water Rice programs provides a further example. They found that the actual yields of

many farmers were higher than the goals set for the Institute's current breeding program, and so redefined the yield targets upward.

10.5.4 Experiment station management

CIMMYT's station managers have worked with people responsible for experiment station management in more than 25 national programs. Eight years ago, CIMMYT introduced a formal training program offering practitioners an opportunity to share some of its experience. Techniques evolved from this work are now being applied in Ecuador, Tanzania, Pakistan, Turkey, Thailand and the Philippines.

10.6 Research Methods

The centers have played an important role in enhancing research methods in developing countries. Many of the methods were innovated at the centers but many others were first developed elsewhere and spread by the centers through their training programs and outposted staff. Among the large number of these methods now in use in developing countries, some representative examples are presented.

One of the most important new research approaches which centers have developed and popularized is the "high volume crossing approach" -- the procedure of making a large number of crosses and exposing them to heavy pressure from relevant pests and diseases. Heretofore the standard plant breeding approach featured a few, carefully chosen crosses which were grown under protected, experiment station conditions. Now the many-crosses-and-heavy-pressure approach has become the convention for most small grains programs around the world.

The techniques that centers have developed to screen lines for disease and pests resistance are among the most commonly mentioned new techniques in the country case studies. Most of the centers have developed such techniques. ICRISAT's technique to screen pearl millet for downy mildew, ergot and smut in the same generation is one such example. Centers have also developed new ways to multiply existing pests in order to put heavy selection pressure on crops. For example, techniques for the mass production of downy mildew inoculum were developed by the Philippine and Thai national programs with CIMMYT collaboration. Techniques for inducing heavy pest pressure are, of course, used only where a particular pest already exists in an ecology. Having cooperating researchers in different ecologies permits evaluation of reactions to pests that do not exist in the home ecology of a researcher.

The centers have also developed important laboratory procedures for testing grain quality. CIMMYT methods for testing the milling and baking qualities of wheat have been spread to many countries through the training programs. Almost all of the milling and baking laboratories in Latin America, for example, have some CIMMYT-trained staff.

Laboratory and other methods for analyzing soils and plants have been developed at IITA, and knowledge of these has been imparted to researchers through annual training courses jointly organized by IITA and the University of Guelph, Canada. The methods have been compiled into manuals that are currently used in laboratories in 46 Sub-Saharan countries as well as in Brazil, Peru, Belize, Indonesia, Sri Lanka, Papua New Guinea, Thailand, Malaysia, India, Hawaii, and Canada. Similarly, method and instrumentation for the assessment of soil erosion and physical degradation of tropical soils

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have been developed and are now being used in Brazil, Ghana, Nigeria, Peru, and Tanzania. IITA has also developed methods for screening herbicides that have been adopted in laboratories in 22 African countries.

10.7 Professional Interaction and Services from the Centers

In addition to the activities discussed above that improve the efficiency of particular research systems on occasion, the centers provide professional interactions and regular services that increase the productivity of national research systems. Some of these services involve communication links between researchers from different countries. Conferences sponsored by the centers on important topics are a means for researchers to keep current in their field, to gain recognition and prestige, and to exchange ideas with colleagues. The international germplasm networks provide national breeders with the best varieties from around the world. Center publications provide both a source of new information, methods and ideas, as well as a place for the "problem-oriented" research worker to publish and gain recognition --- as contrasted to publication in the more "learned" journals.

Networking arrangements associated with the centers have been mentioned at several places already. The most common forms are the genetic materials testing networks discussed in chapters 6 and 2. Any researcher in a network can suggest materials to be included. Researchers in the network participate to the extent that each individual feels is best.

FEATURE: PRECODEPA; A NATIONALLY-RUN REGIONAL COMMODITY NETWORK

Programa Regional Cooperative de Papa (PRECODEPA), was formed in 1978 and now includes all nine of the Spanish-speaking countries of the Central America-Caribbean region. What especially distinguishes PRECODEPA is its structure and function as a collaboration between equals, of which the international center is only one. It is a "mechanism rather than an institution", composed of national programs and CIP. It does not interpose another institutional layer.

National potato programs make some commitment of resources in order to belong to PRECODEPA. Each national program sends two representatives to the Permanent Regional Committee — the national coordinator of potato research and the country's director of agricultural research. The committee agrees on projects of regional interest and appoints a Coordinator and two other representatives who form the Executive Committee which is in charge of executing projects and arranging for their periodic external review. CIP provides specialist assistance and training upon request. A problem is considered to be of regional interest if at least two countries agree it is a factor limiting production or per capita consumption of potatoes. The regional committee assigns priorities to problems by consensus, divides research responsibilities among its members according to interest and comparative advantage, and decides on training and workshop needs and participants.

The members fund their own national staffs and projects. Under a five-year agreement, the Swiss Development Corporation funds the regional component

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of the operating budget drawn up by the Committee: travel, training and some non-personnel "tooling up" costs. This funding has averaged around $250,000 a year.

Seven of the nine projects established in 1978 still continue, with several others since added. Projects originally executed in the respective leader countries have spread to others as local expertise has developed. For example, Honduras has become a partner with Guatemala in the development of rustic storage. Mexico and Costa Rica, originally responsible for seed production, have been joined by Cuba (a new member in 1983). Other projects and leaders include nematode control (Panama), late blight resistance (Mexico), tuber moth control (Guatemala and Costa Rica), development of potatoes for warm humid tropics (Cuba), and a regional socioeconomic project (Guatemala).

PRECODEPA was set up to build national research capabilities and to take advantage of the possibilities of regional specialization and horizontal transfer, by encouraging national initiatives in setting programs and priorities, and working with international researchers. This offsets any tendency to create a permanent dependence on the international centers and the resentment against paternalism that it may engender, and helps to overcome bottlenecks in moving new technology into production.

According to Manuel Villareal, Coordinator of Mexico's National Potato Program and past PRECODEPA Coordinator, "the basic philosophy underlying PRECODEPA is that countries with strong resource limitations and similar agroecological, socioeconomic, and cultural conditions can advantageously divide among themselves the task of developing technical solutions of

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productivity bottlenecks in food crops, and share research results." (ISNAR 1981). The Central America-Caribbean region largely fulfils these conditions with respect to potato production, a minor crop in this area. Such specialization and horizontal transfer can also use international center resources to better advantage, since the center only needs to interact with the regional specialist(s) for a given problem rather than at lower levels with each relevant national program.

PRECODEPA has promoted both national institution building and regional specialization and exchange. There have been sharp increases, some would say excessively so, in potato research and extension staff in member countries, entirely financed from national budgets, and the greater stability of personnel in the potato program than in beans and maize programs, the two principal food crops of the region.

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There are a number of other networks focused on specific research problems (Table 10.4). Examples include the regional research networks for potatoes that are functioning in the Andean countries, in Central Africa, in Central America and the Caribbean (see Feature on PRECODEPA) and in South Asia, in which CIP has been instrumental. A network on soil fertility and fertilizer evaluation on rice is coordinated by IRRI, as is the Asian Farming Systems Network. IBPGR coordinates an extensive network of genetic collection work by joint program planning and a common research core.

Typically, participants in these networks meet once or twice a year to discuss results and modify ongoing work. Leadership rotates among the participants, sometimes being provided by an elected steering committee. A center frequently provides funds for network activities and sometimes also for research but, more often, the main research funds come from national sources or donors. Other centers achieve somewhat similar effects through regional programs. For example, CIMMYT has six regional maize programs, five regional wheat programs, and three additional regional programs in economics. These undertake many of the same activities as those of networks elsewhere.

One advantage of a research network compared to individual research activities is that experiences at various locations can partially substitute for variation over time at a single location and thereby speed the research process. This is effective when the experiences in similar locations within the networks are comparable. It is a particular advantage of small regional networks or even smaller collaborative projects. One year's work in three to five similar locations may possibly substitute for three to five years work in one location, at least for reactions to weather and other factors that vary over time.

Table 10.4 Some international agricultural research networks with center participation

Network	Center participant/ coordinator	Region	Countries	Year started
Proyecto Adino Cooperativeo de Investigacion en Papa	CIP	Andean	5	1982
Programme Regional d'Amelioration de la Culture de la Pomme de Terre en Centrale Afrique	CIP	Central Africa	3	1983
Programa Regional Cooperative de Papa	CIP	Central America and Caribbean	8	1978
South Asia Program for Potato Research and Development	CIP	South Asia	5	1982
Programa Cooperativade Investigacion en Papa	CIP	Latin America	4	
Asian Farming Systems Networks	IRRI	Asia	15	1974
International Network on Soil Fertility and Fertilizer Evaluation on Rice	IRRI	Asia, Africa	19	1976
African Research Network on	ILCA	Africa	18	1980

There are other services that national systems can use on request. The centers provide germplasm upon request to researchers who have a specific problem they are trying to solve. IRRI is working in shuttle breeding programs with the Chinese and Korean national programs and several others to provide faster multiplication of new materials. IRRI also uses its facilities to advance and rapidly multiply photoperiod-sensitive lines for national programs upon request. These collaborative endeavors speed up the selection process, and also subject lines to certain types of stress that are not otherwise as easily and quickly handled.

10.8 Some Pros and Cons of the Centers in Fostering Capacity

The impact of the centers on national research capacity could be judged against the hypothetical situation that would have obtained if there were no international centers. The main impacts of the centers on national agricultural research systems appear, from general observation to be: encouragement of investment in research, shifting research priorities toward food commodities and increasing research output through better organization, improved management, improved research techniques, the provision of germplasm, improving international scientific communication through data base services, international meetings, and publications. The possible negative effects include: diversion of national funds away from research, i.e., a substitution of center for national research (not supported by the analysis described in section 10.9), capture by the centers of funds that would otherwise have gone to national programs, and "pirating" of some of the best national scientists.

The intensity of center involvement varies considerably across countries. In a number of cases researchers or liaison scientists from the centers work in a research program over a period of time (Table 2.2). In such cases, the national program receives a full line of services - personal contact, joint research, training, communication with other scientists at conferences, etc. In most countries, however, none from the centers is stationed in the national system full time, although there are frequent visits by staff (Table 10.5). At the other extreme, some national systems are almost entirely isolated from the system.

There are some alternatives to the centers. In the past the Rockefeller and Ford Foundations epitomized good and successful bilateral programs in providing experts to national programs, but have largely ceased this practice since the establishment of the centers. Bilateral programs of the World Bank with a research emphasis also have offered an effective alternative mode of operation for some countries at different times. What was the International Agricultural Development Service (IADS) now a part of Winrock International, a creation of the Rockefeller Foundation, was organized specifically to assist national research institutions. There are numerous other consulting firms and non-government organizations able to provide advice on managerial and programmatic aspects of research. The FAO also works in this area. Nations face decision problems in selecting from among the various types of assistance offered by these diverse organizations including the international centers.

The primary alternative sources of new research methods for tropical research are the stronger developing country research programs and industrial country research institutions financed by foreign aid agencies. The centers offer services that seem to be efficiently competitive with these

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Table 10.5 Visits by staff of some centers to national programs, 1983

Center	Number of visits by center staff members to researchers and national programs			
	Africa	Latin America	Asia	North Africa Middle East
CIAT	19	148	13	5
CIMMYT	145	291	122	59
CIP	16	99	48	16
IBPGR	24	19	16	5
IFPRI	16	11	31	8
IITA	310	65	24	8
ILCA	121	1	12	14
ILRAD	24	0	2	0
ISNAR	37	8	15	4
IRRI	4	7	262	19

alternatives. In the absence of the centers, it is plausible that fewer techniques would have been developed and, in the absence of the center networks, that these techniques would have spread less rapidly. Cuba provides an illuminating example. It has extensive ties with and is receiving equipment, funds and training from many countries in E. and W. Europe. However, Cuban researchers interviewed in the case study were emphatic that the tropical agricultural focus of the centers was central to domestic research advancement in Cuba. The centers are perceived to provide relevant technological components and research techniques not available to them from elsewhere.

There have always been communications between researchers, and there are many networks outside the CGIAR system. Researchers communicate through professional organizations that hold meetings and publish journals. National research institutions such as the USDA and the tropical agricultural research organizations of former colonial powers support formal and informal networks. They also store and distribute germplasm - some of it through regular varietal testing programs. Bilateral and multilateral aid donors also have provided at times, or continue to provide, communication through conferences and publications, and germplasm. But each of these alternatives is partial and intermittent, in part because the centers now exist and have been welcomed in taking over some of the coordinating roles once executed by others.

There are distinct advantages of the international centers over most of these other organizations. First, relative to international professional organizations, the centers have a larger set of researchers focused on the problems of tropical agricultural production and the type of research they encourage is generally oriented toward the practical problems of farmers.

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Second, relative to support from national organizations, center-provided funding and participation is less influenced by political considerations. Third, relative to the networks sponsored by aid donors, there is more stability of activities over time. Bilateral aid in particular can shift quickly with changing political winds. The international center concept provides some protection against such shifts.

10.9 The Influence of the Centers on National Spending on Research and Extension and on Productivity

As described in chapter 3, national expenditures on research and extension rose impressively between 1959 and 1980. In real terms and in terms of the number of scientists, expenditure grew in all regions. Research "intensities", defined as the percentage of the value of production spent on research, also rose, typically doubling between 1959 and 1980. It was precisely during this period that research spending by the international centers was initiated and expanded strongly. This growth has engendered a debate about the influence of the spending by the centers on investment by national programs.

Some observers have inferred from the contemporaneous rise in both, that the centers have induced more national spending. Others have argued that, as with any form of aid, center spending tends to displace national effort, whose growth would have been even more marked were it not for the presence and growth of the centers. Support for this view point is drawn from the history of particular national commodity programs in countries hosting an international center. Still others argue that, while all centers may not have

displaced national efforts, their funding by the donors came at the cost of reduced effort in bilateral and other forms of multilateral assistance. As a consequence, no net addition to research effort has been made. In short, the range of opinion that abounds spans virtually every possibility.

These issues are both important and complex. Their importance for providing a clearer understanding of the global role and implications of the centers needs no amplification. The fact that different observers can use the same facts to reach opposing conclusions suggests that a number of underlying forces are at work; and only by endeavouring to capture their influence can the true relationships be untangled. An attempt was made with the study to do this but neither the data nor the theoretical constructs are completely adequate for the task. The findings that are overviewed here must, therefore, be regarded as preliminary and further investigation is surely warranted.

In order adequately to address the influence of the centers, it is necessary to disaggregate all research expenditure data by commodity. Interest focuses as much on the center's influence on spending on specific commodity research programs by national agencies as it does on overall research spending. This is because the centers' research, while covering all major food crops, by no means covers all the agricultural research interests of national programs. However, very few countries can provide a breakdown of research expenditures by commodity, and certainly fewer could offer this on an annual basis. Even where it is attempted, arbitrary allocations to individual crops of expenditures on such areas as soils, irrigation, pastures and fertilizer must be made. In this analysis (reported separately in a Study Paper by Evenson 1985), estimates of national expenditure on a particular commodity were made by allocating the reported total agricultural research

budget on the basis of data about publications obtained from the Commonwealth Agricultural Bureau and an adjustment for expenditure per publication using weights derived from a Brazilian study and applied to the other 24 countries in the sample. To the extent that relative costs of research on various commodities differ or countries vary their share of research in a particular commodity over time, the constructed series will be in error. Furthermore, if spending by the centers induces changes in the share as well as the total level of research, the results will fail to capture this.

Data for commodity research expenditures by country generated in this manner are summarized by region in Table 10.6. The research expenditures are expressed as a share of the value of output. Four points emerge from this table: (a) The research intensities across commodities are very uneven, (b) the research intensities for a commodity vary widely across regions; for example, rice research in Latin America is twice the level of rice research in Asia, (c) in almost every commodity, the research intensity in Africa is higher than other regions, (d) the share of the centers in total research funding varies widely. Globally, the centers' research represented 15 and 21 percent of cassava and potato research, but only 4 percent of rice research. This suggests that either the centers are over investing in roots and tubers relative to cereal research or that national programs are underfunding roots and tubers and the centers are compensating partially for this, or that the marginal return on center research in roots and tubers is significantly higher than in cereals. Only by formulating and testing such hypotheses will a clearer understanding of the centers' role emerge.

It is not possible to include all countries in this analysis as data for many of the variables used were not available, and so only 25 countries are

Table 10.6 Research spending by national and international programs: Average 1972-79 for 25 developing countries (percent)

Commodity	National research expenditures as a share of value of output			Spending by centers as a share of total research expenditures
	Africa[a]	Asia[b]	Latin[c]	
Wheat	1.30	0.32	1.04	4
Rice	1.05	0.21	0.41	7
Maize	0.44	0.21	0.18	11
Cassava	0.09	0.06	0.19	15
Beans	1.65	0.08	0.60	11
Pototoes	0.21	0.19	0.43	21
Groundnuts	0.57	0.12	0.60	2
Beef	1.82	0.65	0.67	2

a Ghana, Kenya, Nigeria, Sudan, Tanzania, Tunisia, Uganda, Egypt.

b Sri Lanka, India, Taiwan, Pakistan, Indonesia, Thailand, Philippines Korea, Malaysia, Turkey

c Argentina, Brazil, Chile, Colombia, Mexico, Peru, Venezuela

included; eight in Africa, ten in Asia and seven in Latin America. Together, these 25 countries produce over 90 percent of the total value of agricultural production in the developing countries excluding China.

For the analysis of the influence of the centers on national spending, two sets of data were constructed. The first involves observations for two periods, 1972-75 and 1976-80, for the 25 countries. For this set, data on various measures of foreign assistance were available enabling the influence of foreign aid on domestic spending to be considered. The second set has annual observations from 1962 to 1982 but includes only a limited number of variables. In both sets, observations are for a country, a commodity and a year. Twelve commodities were analyzed; ten from the centers' portfolios (rice, wheat, maize, sorghum, millet, cassava, beans, potatoes, sweet potatoes and groundnuts), together with soybeans and sugar. The approach taken was to specify a set of variables that were expected to explain the level of funding of national research and extension programs. A statistical analysis was then undertaken to determine the importance of each of these variables, after allowing for the influence of the others. National research expenditures by commodity, and total extension expenditures were specified in millions of constant 1980 US dollars for each country. The explanatory variables fell in three categories: economic, international and political. The economic variables featured were: the value of commodity production, an index of diversity among cropping patterns across geo-climatic regions, the relative costs of research and extension, and an index of land scarcity. The international variables intended to capture the influence of centers and others included: the cumulative spending by the centers on a commodity including an interaction effect with the total area in crops to allow for the likely complicating influence size of the country, the research investment by

neighbours in similar geo-climatic regions and a variable denoting whether or not a country is host to a center. The political variables employed captured aspects of: the extent of international trade, an index of farmers' terms of trade, the agricultural labor force as proportion of the economically active population in agriculture, an index of urbanization of the population, and an index of political violence. Allowance was made for the fact that the amount of foreign aid is itself influenced by the level of domestic research spending as well as being a determinant of that spending.

Detailed interpretation of the econometric results is available in the separate report by Evenson and also in Evenson, Pray and Scobie (1985). Only an overview of the empirical estimates is offered here. The overall effects of centers' induced investment are strongly complementary. Apparently in part in response to centers' cumulative investment in research on a commodity, national programs also invest in it — generally in a manner that rapidly (in from one to five years) matches the total amount invested by the CGIAR. The analogously associated changes in national expenditure on extension are usually an order of magnitude smaller.

The influence of the centers on domestic spending on both research and extension was found to be strongly related to the size of the country. Larger countries can benefit more from any given unit of research output from the centers simply because of their greater area of crop production. Hence, in absolute terms, they are encouraged to expand their own research funding by much more significant amounts following an increase in center funding. Not only do larger countries increase their spending by greater absolute amounts but their research expenditures per unit of crop area also rise. Larger countries apparently find it more worthwhile to expand research intensity than do small countries. Very small countries may reduce their research efforts in

the face of increased spending by the centers, drawing more heavily on support from the centers.

In contrast to the marked rise in national funding from an increase in center expenditures, there seemed very little net increase in research expenditures following a rise in general aid for research. For World Bank assistance to research there may be an even more severe displacement effect although a Bank loan for extension has a significant stimulus effect on national extension spending.

The overview thus far refers to non-host countries. For host countries there was no clear-cut relation between center and national spending. There was some suggestion that the effect has been positive but there is a difficulty in implying any causality. It may be that the centers have been located in host countries with a greater proclivity for expanding their agricultural research spending. When neighbouring geo-climatic regions increase their research effort, a country is typically induced to raise its own research efforts to internalize the benefits stemming from the greater regional research output. Similarly, where exports of a commodity become more important, research and extension effort is increased, and, in particular, greater output induces more research spending. Typically, a 10 percent rise in the value of output is accompanied by a 6 percent increase in research and extension spending.

On a commodity by commodity basis, spending by the centers was found to have a significant effect on national program spending on all the cereals except millet. While the effect on other staples as a whole was significant, individually, only in the case of potatoes was there evidence that spending by

national programs is related to the expenditure of the centers. Additional cumulative spending by the centers was found to have induced more than proportional spending on cereal research by national programs. For both cereals and staples, strong complementarity with rather than displacement of national effort was suggested by the econometric results.

An annual data set on commodity research in the same 25 countries for the years 1962 to 1982 was used in a further analysis addressed to the effects of research spending on production. The value of output of particular commodities was related to: measures of national research and extension, international research spending, area of the crop harvested and measures of the use of irrigation and fertilizers.

It is highly improbable that the influence of centers would be the same in all 25 countries, as generally centers will produce technology more closely matched to the circumstances of their host countries than to dissimilar environments. This will affect the productivity of the center's contribution and its interaction with national research and extension programs. A variable was defined to capture the extent to which a country's production of a particular crop takes place in the same geo-climatic zone as each center's principal location.

For any given level of research funding, it is of interest to ask whether there are positive or negative interactions between national and center funding. They were indicated as being generally positive for beans and sorghum but negative for wheat, cassava and potatoes. In similar geo-climatic regions, the effect was positive only for wheat. In similar regions the centers' technologies should more nearly match the requirements of the

national programs, so that center funding may not interact significantly with national funding to raise crop productivity. In short, the interaction effects measured between center research and national research and national extension spending provided general support for the notion that there is a substitutive rather than complementary effect between national and center efforts in similar zones.

Clearly, the productivity of national research and extension efforts varies tremendously across countries depending on organization and leadership, and the economic and political setting. The results pooled across the 25 countries must thus be regarded cautiously. Of major significance in the present context is the contribution of the centers.

It is instructive to overview first the results for the two broad groups: cereals and staples. In both cases, national and center spending raises observed productivity, the latter the more so in regions of greater geo-climatic similarity. Total center spending as a proportion of the value of output is quite low so that a small rise in cereal productivity over the entire cereal areas of 25 major countries implies a very substantial impact. Furthermore, the value of increased output far exceeds the research and presumably also other associated costs. For example the value of a 0.3 percent rise in cereal output might be, say, $130m a year globally while a 10 percent rise in spending on cereal research by the centers would represent an annual cost of only $7m and an implied marginal internal rate of return of the order of 100 percent. A rate so high follows from the fact that the contribution of the centers occurs not just in one country but over entire regions. Results for individual cereals were, however, found to be rather erratic. In the staple crops within similar regions, there were found

significant impacts of center spending on cassava, beans and potatoes. Cassava research has not seemingly raised productivity outside its own regions, however.

In summary, the evidence shows that spending by the national programs is positively related to spending by international centers. The centers' products include germplasm, research methods, information and training. These form intermediate inputs in the production of adapted technology by national systems. The productivity of their own investment is enhanced by the presence of these inputs. The effect is greater in countries with a larger cropped area because a unit of research effort generates results that can be more widely applied. In small countries, there is much less additional spending in response to the centers. This suggests that the centers should continue to foster mechanisms which raise the productivity of research in small countries and so encourage them to increase their research efforts.

The influence of spending on particular commodities presents a varied picture. In general, the spending on cereal research has engendered a greater corresponding response by national programs than has research on staples, although potatoes are a notable exception. It seems that research on staples has still to build up the accumulated stocks of knowledge that have come from the longer and more intensive history of cereal research. This result reflects the long lags inherent in crop improvement research, especially on an international scale. However, there are features of both the supply and demand for staples which have implications for the level of national research funding. They are often produced under small-scale, partly subsistence conditions in more remote rural areas; the ability of these producers to influence the allocation of resources at the national level is frequently very

limited. Furthermore, the demand for staples does not rise with increased incomes to nearly the same extent as does the demand for cereals. The share of the budget spend on staples falls sharply as income rises. In contrast, the demand for cereals for both direct and, even more crucially, for animal consumption is rising rapidly in developing countries. This, combined with their greater importance in trade, leads to higher research expenditures than for staples in most regions.

In contrast, the effect on productivity of centers' spending on staples in developing countries has seemingly exceeded that of cereal research. This may reflect the opportunities that have existed to make initial gains in previously neglected crops. In both cereals and staples, the centers' contribution to improved productivity is greater in geo-climatic zones similar to their own. The generally high rates of return associated with the research investment by the centers should signal the need for sustained spending on research.

Finally, it has to be stressed again that investment in research and extension, and the growth of agricultural productivity, are governed by the complex interplay of economic and political forces which occur in a wide variety of social and cultural settings. Understanding of these forces is less than complete and the data are less than ideal in their coverage, detail and quality. For these reasons, it would be premature to accept as definitive these overviewed findings. They do, however, represent a first attempt to estimate the effect of the centers on both funding and productivity while allowing for the impact of several of the other economic and political forces that might reasonably be expected to influence these two key dimensions.

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10.10 Coda

* The growth of national agricultural research systems and international research centers are mutually reinforcing processes. International centers cannot have much impact on farming unless there are researchers to do adaptive work at the national level and extension workers to help to take ideas to farmers.

* The aggregate growth of national research systems over the past quarter century has been rapid but some important activities cannot readily be carried out by some national institutions and many national programs still have important weaknesses. The international centers continue to have an important role here.

* One of ILCA's more important products to date has been the analytical services that it provides to national agencies which have large data bases on animal production. Researchers analyze the data at ILCA with the assistance of ILCA staff. The results have also been used to assist in the preparation of livestock development projects.

* On-farm research programs have been promoted by the centers and are being used by national researchers as an input into the research planning process.

* CIMMYT's station managers have worked with people responsible for

experiment station management in more than 25 national programs. Some of the techniques evolved are now being applied in Ecuador, Tanzania, Pakistan, Turkey, Thailand and the Philippines.

* One of the most important new research approaches which centers have developed and popularized is the procedure of making a large number of crosses and exposing them to heavy pressure from relevant pests and diseases. Techniques for the mass production of downy mildew inoculum were developed by the Philippine and Thai national programs with CIMMYT collaboration. CIMMYT methods for testing the milling and baking qualities of wheat have been spread to many countries through the training programs.

* The centers provide professional interactions and regular services that increase the productivity of national research systems. They play an important role of linking national agricultural research systems together through research networks which may take a wide range of forms. Some are networks focused on specific research problems. IBPGR coordinates an extensive network of genetic collection work. One advantage of a research network compared to individual research activities is that experiences at various locations can partially substitute for variation over time at a single location. Collaborative programs speed up the selection process, and subject lines to certain types of stress that are not as easily and quickly handled otherwise.

* International research centers can influence national research capacity (a) by indicating the importance of research, (b) through projects to build national institutions, and (c) through the regular services they provide to the national systems.

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* The existence of the CGIAR has considerably affected the level of finance available for national agricultural research. Collaboration with the centers raised the productivity of research and helped to convince governments that there are high returns to research.

* The Rockefeller and Ford Foundations have long been concerned with world food problems, and they took strong leads in supporting agricultural research addressed to their solution. Asian food production has clearly justified that support. There is less evidence of research benefit in Africa, where the investments were made later and the base of commodity-specific knowledge was generally lower.

* The inducement effect on research priorities is clearest where counterpart commodity research programs did not exist prior to center involvement. For example, only India had a national cassava research program before CIAT was established. Collaboration has led to increases in the size of existing programs in many countries. National research investments increased more rapidly for commodities being researched by the CGIAR centers. For example, Syria's research on field crops corresponding to ICARDA's activities made up about 42 percent of the projects in 1978, while by 1984 it made up 73 percent.

* Some cases are cited as examples of centers "crowding out" local research, especially in countries that host centers. IRRI research appears to have been a partial substitute for national rice research in the Philippines, for example.

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* Some of the specific commodity programs instituted with center stimulation have attracted comment because they absorb significant research resources on commodities which make up a small share of the value of output (e.g. potatoes in the PRECODEPA countries).

* CIMMYT's emphasis on breeding maize composites rather than hybrids has had a significant impact on many maize research programs in Latin America and Asia.

* Perhaps the most important impact of the centers on research priorities has been the orientation of researchers toward solving farmers' problems. Researchers in the centers provide prestigious role models for national research workers. Training programs at the centers also stress applied research in farmers' fields. The Nile Valley project of Egypt and Sudan in which ICARDA is centrally involved is a good example of encouraging national scientists to work on farmers' problems in farmers' fields. The centers have actively encouraged use of intendisciplinary teams.

* Some national institutions have used the structure of centers in designing their own activities. For example, EMBRAPA in Brazil established a series of commodity institutes organized in multidisciplinary teams as the basic structure for its new national agricultural research system.

* ISNAR assists countries in the identification of desirable organizational changes and needed support. It has recommended institutional and organizational change in 12 out of the 18 countries where its major review and planning missions have been completed. More than 130 individuals, most

from Africa, have participated in ISNAR's research management training programs.

* IBPGR has been responsible for some important new institutions - the development of new national genetic conservation programs in about 50 countries and the development of national genetic resources committees in 25 countries.

* The main positive impacts of the centers on national agricultural research systems appear to be: encouragement of investment in research, shifting research priorities toward food commodities, and increasing research output through better organization, improved management, improved research techniques, the provision of germplasm, improving international scientific communication through data base services, international meetings, and publications. The possible negative effects include: some diversion of national funds away from research covered by centers, capture by centers of funds that may otherwise have gone to national programs, and loss of key national staff to the centers.

* In the absence of the centers, it seems likely that there would have been fewer improved farming techniques developed and, in the absence of the center network, these techniques would have spread less rapidly.

* Spending on research by the international centers may influence the level of spending by national programs. The centers provide genetic materials, research methods, training and information. These represent intermediate inputs into the production of new knowledge and technologies by national programs.

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* Where these products of the centers are closely tailored to match the ecological circumstances of the collaborating countries, the presence and spending of the centers may displace national research efforts. On the other hand, the provision of these products by the centers could be expected to provide both greater opportunity and capacity for national programs to test, adapt, modify and disseminate technologies relevant to local conditions.

* An analysis of the factors determining national spending on research and extension was undertaken. A wide range of economic, international and political variables which might be expected to influence national spending was included in order to isolate the effect to the centers' activities. Data for 12 commodities in 25 countries were used.

* An increase in the total spending by the centers on field crop research was found to be associated with increased spending on both research and extension by national programs. Investment in research by the centers appears to have a greater enhancing effect on national spending than other forms of aid.

* The amount by which national spending rises in response to increased effort by the centers is strongly influenced by the size of the country. Countries with large areas of crops can capture more benefits from the products of the centers simply because there is a greater scale of production to which to apply new technologies. They increase their funding both absolutely and relatively more than small countries. The risk of displacing national efforts is much greater in small countries.

* Increased research effort by neighbours in smaller geo-climatic zones

also seemingly induces greater national research spending as countries have expanded possibilities to capture relevant technologies.

* Research spending by both national and international agencies raises agricultural productivity. In general, a 10 percent rise in the expenditure by nations and centers on a particular commodity subsequently raises national productivity by about 1.1 and 0.3 percent, respectively. Because the results of center research are applicable to wide regions, the implied marginal rates of return are very high - of the order of 100 percent.

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11 AGRICULTURAL AND FOOD POLICIES

11.1 Introduction

11.1.1 Need for research

Preceding chapters in this Part have addressed the contribution of the centers stemming from the generation of new technology. Much has been accomplished; new varieties, improved cultural practices, an increased stock of knowledge and research capacity, have all led to notable gains. Yet it is clear that increased output alone does not lead automatically to improved food consumption, nutrition or human welfare. Even in the early 1970s during the years of poor harvests, the global supply of calories from basic grains alone exceeded the arbitrary level of average per capita requirements by more than 20 percent. A few years later in 1978, supplies exceeded requirements by almost 50 percent, and this is without counting the energy derived from oils, sugar, meats, fruits and vegetables and pulses. Despite this apparent abundance of total supplies, many millions of people remain inadequately fed.

While global output has risen, due in no small part to the combined research efforts of the national and international centers, the agricultural and food economy has been characterized by uneveness across regions and countries, and variability through time. Agricultural development and food production have been uneven; growth in food consumption has been unevenly distributed, and food prices, while generally continuing their long decline over many decades, have been rather more volatile.

Why has the effect of technological change in agriculture been so uneven both within and between countries? Why has food consumption been so much lower and subject to greater variability in some countries than in others?

Why have prices fluctuated? Why does the distribution of gains from new technology differ so markedly?

Relaxing the biological constraints to production has been an important force in the world food economy. It must continue to be so, demanding the sustained efforts of both the national and international components of the global research system. However, to understand (and influence) the consumption of food, both in its level and reliability, requires attention to the economic, political and institutional environment. Here, the issues transcend those of technological change, par se. Production, consumption, distribution, foreign trade and prices of food reflect economic, political and institutional factors as well as the technological circumstances.

It has become increasingly evident that the supply of relevant technology for food production is a reflection of conscious decisions made about the level and nature of investment in research. In an analogous manner, the economic and institutional setting is itself a reflection of deliberately chosen policies. Furthermore, the development of richer theories, together with a greater body of evidence has highlighted the fact that it is not only those policies directly related to or arising from the agricultural and food sector that are of importance. A broad range of economic policies, be they monetary, fiscal, trade or international policies, influence the production, distribution, consumption and pricing of food. These policies have a direct and important bearing on: (a) the supply of technological change; (b) the demand for technological change; and (c) the impact of technological change. Research which leads to an improved understanding of the nature and role of policies, and helps to alleviate the constraints they impose, is an important element of global agricultural research.

11.1.2 Diversity of issues

Agricultural and food policy embodies the collective efforts of national and international agencies to influence the environment of producers, consumers and traders. Such intervention is directed at achieving such social goals as improved nutrition, higher rural incomes and employment, greater self-sufficiency, and improved food security. Research on food policy involves (a) the development of analytical schemes which, when bolstered with empirical evidence, reveal the complementarities and conflicts between the various objectives; (b) identifying the instruments through which both national and international intervention policies can be implemented; and (c) quantifying the effect of changes in policy on social objectives.

In order to undertake such research effectively, food policy analysts must concern themselves with issues ranging from food production, the generation and diffusion of new technology, the enhancement of the physical and human stocks of capital, the distribution and pricing of food, and the roles of trade and international policies. In every case, there is a multitude of policy alternatives which directly and indirectly affect such outcomes. The wide scope of the issues and the range of potential instruments make the resulting analyses complex. There are no easy alternatives. Some indication of the scope of food policy questions can be gauged from the following example.

In many developing countries, overvalued exchange rates have been a characteristic of attempts to accelerate economic development through industrialization. The results have been to lower the price of tradeable relative to non-tradeable goods. Imports are made cheaper (although their quantities

are often restricted), and exporting becomes less attractive. The implications for the production, consumption, and trade of foodstuffs of this economic development strategy, seemingly unrelated to agriculture, are manifold.

The strategy will tend to hold down the local price of tradeable foodstuffs, providing protection for low-income consumers. But depressed prices will discourage domestic production and result in less incentive to invest in agriculture, be it in research, education, extension or physical capital. Such investment will appear less attractive when agricultural output is undervalued. Resource allocation between the sectors will respond accordingly.

At the same time, output, employment and income growth in agriculture will be held back. This will encourage migration out of agriculture - a tendency further enhanced by the attraction of higher urban wages, a result of labor unions capturing part of the rents generated by industrial protection.

With a rising urban population and declining, or at best stagnant, food production, pressure will be placed on the government to import food to hold down prices and wage costs. Continued poverty will result in pressure for food subsidies for some, or even all, of the population, certainly in urban areas. The combined effect of increased food imports and subsidies on consumption will be to place additional pressure on both the internal and external accounts of the country. Balance of payment difficulties will be worsened by a decline in agricultural exports.

To hold down the budgetary costs, the government may instigate forced deliveries of food by local producers, ironically at prices significantly below those which it pays foreign producers for imported supplies. When foreign exchange crises arise there will be little scope to cut food imports made "essential" by the other strategies being pursued. Imports of capital goods can be curtailed, reducing the growth of the capital stock; and imports of raw materials will be retained, reducing the utilization rate of the installed industrial capacity. Employment and output in the industrial sector will tend to be destabilized.

This simple example serves to illustrate the breadth and complexity of the issues in food policy analysis. In countries where agriculture is an important sector, the connection with the rest of the economy will be significant and complex. Food policy research faces a dauntingly diverse menu of important issues.

11.1.3 Design of technology

Of particular importance to the work of the CGIAR is the role of policy research in the design, generation and diffusion of new agricultural technology. A significant contribution of such work may be to assist biological research workers to justify their work, and to orient their work to achieving a broad spectrum of social goals. Some examples will serve to illustrate this role of policy research.

In an attempt to raise nutrient intakes, plant breeding programs are sometimes directed toward enhancing the nutrient quality of a crop. This may involve both a long and difficult task and some tradeoffs with gains in productivity. Higher protein content in rice, for example, generally only

comes at the cost of lower yields. Could an equal gain in nutrient intakes be achieved by altering the mix of crops? What is the gain if increased output alone is the target? How will the production of other crops be affected? What are the effects on employment and incomes and hence on the demand for food? How are these changes distributed between the poorly and the adequately nourished? Are there other instruments (maternal and child care, health services or food subsidies) that might be used to address the nutritional needs of a specific group? How effective are these? Are they cost-efficient? Such are the questions to be addressed by the policy analyst.

Concern has been expressed about increased variability in the yields and output of food crops. A natural and immediate reaction is to focus on the genetic improvement and the associated agronomic practices. Can varieties be developed with greater ability to withstand disease, inadequate fertilizer or water, extremes of heat, etc. But the problem calls for a much more complete assessment of the causes and magnitudes of instability, combined with a broad perspective on the wide range of possible instruments. Would other changes in the farming system offer less costly ways to enhance stability? Could the mix of crops be altered? Would more ready access to fertilizer and pesticides reduce variability? Would investment in irrigation schemes lower the risks? Would crop insurance ameliorate the effects of instability? Would holding additional buffer stocks or greater reserves of foreign exchange be an effective means to lessen the variation in consumption? Would improved access to domestic water and fuel supplies release labor for crop protection tasks? Would concentration on achieving higher yield alone reduce the need to expand production to more marginal areas and so lessen the variability of output? An apparently straightforward technical matter is, in fact, amenable to a host of

potential approaches that may be made more explicit in effective policy analysis.

In a cassava growing area of Colombia, large-scale farmers achieved high yields from monoculture while, alongside, small-scale farmers used complex multicropping systems that yielded much less. An initial reaction of researchers was to emphasize the need for improved cassava varieties tailored specifically for multi-cropping systems of the small farms. It seemed that not only should yields be an objective of the breeding program, but plant architecture, timing of maximum foliage density, and length of growing cycle should all be reflected in the breeding strategy. It was argued that only by incorporating these criteria into the breeding strategy would technology be produced relevant to the circumstances of the small farms. On closer inspection, however, it was learned that these farmers used a multicropping system as it lowered the need for pesticides, although the total net returns were much lower than from intensive monoculture. Because of a subsidized credit scheme, there was excess demand for credit. This was handled by the use of non-price rationing methods which excluded the small-scale, politically powerless, illiterate farmers. Without credit they could not acquire the inputs needed to produce high-yielding crops of cassava for a profitable fresh market. In such circumstances, it is conceivable that an increase in the interest rate on agricultural working loans would raise the output and net incomes on small farms much sooner and much more substantially than breeding for a cassava type to suit a multicropping system. Only through the effective collaboration of breeders, agronomists, and economists would such issues be addressed.

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Attempts are currently underway to remedy the poor performance of African agriculture. Appropriate steps will only follow correct diagnosis, which itself will require assessments of both the technical and policy environments. Has the slow growth and declining output per head been due to lack of relevant new technologies? Does much of Africa, in fact, face shortages of labor rather than of land? Has enough attention been given to the policy and practical implications of the facts (FAO 1984a,b) that women contribute an estimated two-thirds of all hours spent in traditional African agriculture, three-fifths of the hours spent in marketing and, in most areas are the primary producers of food for domestic consumption? Has the spread of new technology been impeded by policies that undervalue the output of agriculture? Have those discriminatory policies themselves altered the rate and direction at which new technology has been generated?

Since its inception, the CGIAR has been concerned to try to ensure that the main share of any benefits stemming from technological advances is captured by poor people. By quantifying the effect of a technological change on the demand for factors, labor income and consumption patterns can provide a better understanding of the links between technology and income distribution. In short, a concern for equity must involve research on both technological and policy issues.

12.2 Policy Research in the CGIAR System

12.2.1 History and objectives

From its inception, the Consultative Group was concerned with issues of food and agricultural policy, particularly insofar as these impinged on the generation and diffusion of technology for food production. A seminar on

socioeconomic research in the centers was convened in 1973, and the matter was subsequently taken up by the TAC. In July 1974, the Chairman of the TAC presented a recommendation to the CGIAR for the establishment of an international center to undertake studies in key policy issues relating to world agricultural development, particularly to food problems. At its meeting in October 1974 the TAC proposal had been further considered but had failed to receive a clear consensus of support. It was agreed that the CGIAR would take no further action at that time, although it was recognized that some individual donors may wish to; in that event, the CGIAR expressed interest in maintaining close links. Finally, after the results of the pending world food conference were known, and in view of the pioneering nature of such a venture, the Group agreed it would be prepared to reconsider the question of sponsorship at some time in the future.

IFPRI was formally incorporated in early 1975, receiving its funding from a group of three donor members of the CGIAR. In 1978, the sponsors sought to have the Institute's funding transferred to the CGIAR and, following a TAC recommendation, this was accomplished in 1979. The TAC recommended that IFPRI's mandate should give principal emphasis to problems in developing countries, and that it should focus on the linkages and interrelationships between the farm-level problems of the adoption of new technology, and wider socioeconomic aspects of agricultural development.

11.2.2 Current research on policy in the CGIAR system

Research related to food and agricultural policy is undertaken by (a) a majority of the individual centers, (b) IFPRI, and (c) TAC and the CGIAR Secretariat. Social scientists are on the staff of 11 of the 13 centers (ILRAD and IBPGR being the exceptions).

Policy research in the centers

There are basically three different types of organizational arrangements for research on policy matters at centers other than IFPRI. (While ISNAR's work does involve social science research and is related to policy, specifically to the funding and management of research, it is not included here; see chapter 10). The organizational approaches can be classified as Systems, Disciplinary or Commodity.

(a) Systems Approach: Social science work is included as part of a farming systems group. This model is used by ICARDA, IITA, ILCA, and IRRI, (the latter having a small portion of its economics resources in the Farming Systems Program).

(b) Disciplinary Approach: Social science work is conducted by a separate department of economic or socioeconomic research. This is the case in CIMMYT, CIP, IRRI, ICRISAT and WARDA. In addition, ILCA has a Livestock Policy Unit. Much of the work undertaken by the centers with disciplinary denominations is actually closely linked with farming systems research.

(c) Commodity Approach: In this model, adopted only by CIAT, all social science work is conducted as part of multidisciplinary teams each addressing research for a particular commodity (tropical pastures, beans and cassava).

The primary focus of social science research in these centers is the generation and diffusion of new technology. Understanding the technical and economic circumstances of producers, using that information to guide the development of new technology, estimating the payoff to alternative research

strategies, collaborating in trials on station and farms and documenting the adoption and consequences of new technology, are the activities which form the core of the social science research done by the centers.

Overall, aside from IFPRI, here has been little work directed specifically at food and agricultural policy per se. To engage in such work is generally seen as diverting resources from the immediate targets of biological research. It was felt for a long time that such matters were solely the domain of national governments and that, to be seen to be addressing domestic policy questions, would imply an intrusion into sovereign affairs which might jeopardize good working relationships with national programs and their political masters. An international center could legitimately collaborate with the scientists in a country and influence their aims and methods. This was seen (perhaps naively) as a politically neutral activity. To engage in direct contact with policy makers was seen as risking accusations of political meddling.

In practice, however, the individual centers have found themselves faced with a continuous need to assess the policy environment in a country, just as much as they must assess the agro-ecological circumstances. This has lead some of them to examine systematically the structure of incentives facing producers and consumers of the particular crop in question. The work on maize and wheat by CIMMYT in a number of countries is a notable example of this type of policy research. It does raise a difficult question for the centers: should they endeavor to improve crop technology in a setting which is agronomically favorable but where the structure of incentives is so unfavorable that any widespread adoption seems unlikely? Do they take the economic climates as given? There is no definitive answer to such a problem.

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Economic climates can and do change and, by undertaking this type of research, a center is better able to know where its work may have impact and thus to, allocate its own resources efficiently, and at the same time to engage in discussions with national policy makers on the basis of concrete analyses.

A number of the centers (notably CIAT, CIMMYT, CIP, ILCA, and IRRI) produce periodic statements of statistical trends in output, prices, trade and consumption for the crops in their mandates. These are particularly useful. The recent issues from CIMMYT also contain carefully researched and documented essays which synthesize important global developments for the crops. There is a very wide potential audience for this material and it plays a useful role. The other centers might consider preparing such statements and giving them wider distribution. At present a number are produced and used only within - center.

As a result of continued close scientific collaboration, both economists and biologists at the centers have had informal contacts with those responsible for setting policies. Frequently, these contacts have arisen as a logical consequence of potential technological advances. The introduction and spread of a new variety may depend heavily on the supply of inputs, the delivery of water, the provision of transport and processing facilities, the prices paid to producers, or the availability of credit. By generating potentially significant advances, the technical possibilities facing a country are altered. This creates disequilibria, the very essence of technological change, and calls for a whole series of responses, many falling directly in the domain of public policy.

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Through this indirect mechanism, the centers, while focusing primarily on the generation of new technology, are, in fact, legitimately involved in discussions on policy issues. In some cases, this has encouraged them to undertake some specific research activities related to policy matters, and to launch some new initiatives, such as the policy unit at ILCA.

This recently formed unit has three objectives: (a) to identify major policy questions relating to African livestock development; (b) to conduct research on selected issues; (c) to bring the results to the attention of those making policies for the sector. Current work includes a study of the size and composition of public expenditures for the livestock sector and the consequences for African consumption and production of increased imports of dairy products. The first major study completed was an analysis of the markedly different performance of the livestock sectors in various African countries from 1965 to 1980, explaining differences in the rates of growth of livestock production. Information about the relative importance of technical and policy constraints in different settings can be of value to both the center itself in setting its priorities for biological research, and to national policy makers.

Such undertakings by individual centers must inevitably stimulate debate about the role and scope of policy research in the CGIAR system as a whole and the best way to conduct the policy research that is found to be germane to the CGIAR mission. There will always be issues that are directly linked to particular technologies or regions and which consequently lend themselves to being addressed by the individual centers. It is arguable that the future impact of the centers may well be higher to the extent that both the scientific staff and the leadership are constantly informed of changes in

economic climates and global trends that affect the countries and crops in their mandates. The risk of such efforts is that they become piecemeal, sporadic attempts built on an inadequate base of analytical capacity and experience in policy issues. As some of the important issues are more global than local, a proliferation of policy research in the centers would inevitably suffer from some duplication. To ensure that the maximal contribution is obtained from resources devoted to policy research in the CGIAR system, continued scrutiny will be needed to determine the best allocation of efforts between IFPRI and the individual centers.

IFPRI

While less than one-third of the total social science staff of the CGIAR system is in IFPRI, its mandate is designed for it to undertake the majority of the research on policy matters. While the micro-economic focus of the work done at the centers has always been seen as valuable, the TAC felt that many policy issues arising from the work of the center economists, and macro-economic policy issues such as commodity trade and price policies, were neither adequately addressed nor appropriately undertaken by the existing centers. For this reason, the system was seen to have a weakness to be remedied by the inclusion of IFPRI.

IFPRI's work is organized in five research programs:

- Agricultural Growth Linkages and Development Policy
- Food Data Evaluation
- Food Production Policies
- International Food Trade and Food Security
- Food Consumption and Nutrition Policy

In 1982, a long-term plan was developed in which the work of each of these programs was integrated and focused on six principal questions:

1. What food policy adjustments are needed in response to rapid growth in food import demand by developing countries?
2. What policies will allow technological change to play its central role in raising food production in developing countries?
3. What combination of farm product incentives can achieve growth and equity simultaneously?
4. What relative weight should be given to alternative agricultural commodities in future production patterns?
5. What policies are needed for technological change in agriculture to stimulate the growth of income and employment necessary to alleviate rural poverty?
6. How can food security be provided to the world's poorest people in the face of unequal distribution of income, fluctuating production, and high costs of storage?

With the creation of IFPRI, the CGIAR system now has the capacity to review both the on-farm and intrahousehold constraints and the policy constraints to greater food production and improved welfare. There is a natural specialization which follows from the comparative advantage that the other centers have relative to IFPRI. Many of the on-farm issues are highly locational specific or relate to the regions for which the individual centers have their mandates.

One of the criteria for guiding the evolution of the CGIAR system has been to contribute to areas of research not adequately addressed by others. Research on basic foodstuffs had frequently been neglected in developing

countries, and the efforts of the CGIAR have always been seen as contributing to filling this gap. Given the critical role of the agricultural sector in economic development, there has probably been substantial underinvestment on research in agricultural and food policy in developing countries. In a manner analogous to the role of the centers in filling gaps in biological research, IFPRI has a role to compensate for some gaps in policy research. By concentrating a critical mass of skills and resources in a centralized agency, IFPRI is able to undertake this role in a presumably cost-effective manner.

The CGIAR Secretariat and the TAC

Finally, both the Secretariat and the TAC periodically sponsor studies related to the allocation of research effort, the establishment of priorities, and the evaluation of the impact of research. These have implications for policies within the CGIAR system, for other international agencies, and for national governments.

11.3 Contributions

11.3.1 Evaluation and attribution

In this section the realized contribution of research on policy within the CGIAR system is addressed. Such an exercise is beset with even greater difficulties than those confronting the evaluation of the impact of new biological technology. The spread of a new variety does provide some tangible evidence of technological advance, and at least some data on areas and yields are usually available or can be estimated. Identifying even the existence of a new policy can, in and of itself, be a difficult task; isolating what its impact may have been is fraught with pitfalls. Of particular importance is the question of attribution. Even to ask what the impact of policy research

by the CGIAR system has been is to raise questions about the legitimate role of the system in relation to sovereign states. Policy research can only have an impact if its findings lead (a) to changes implemented in actual policies, (b) to the avoidance of unwise policies or (c) confirmation that existing policies are best. But such results depend on decisions by national governments and to attribute any actual impact to the CGIAR could easily be construed as politically insensitive, and by some as evidence of meddling in national affairs. More particularly, it is seldom realistic to try to segregate the effects of particular pieces of policy advice or analysis from all the other inputs that go into policy formation. For these reasons, it is deemed appropriate to view the impact of research on policy as coming through the generation of new knowledge about alternative policies and their outcomes, and the contribution that such knowledge makes to informed debate surrounding policy decisions.

11.3.2 Policy studies

In this section, some selected examples are discussed to illustrate the role that policy research is playing, the nature of the links that have been forged, and the contribution of the new knowledge to policy making.

Contribution of biological research to policy making

As stressed in section 11.2.2, the principal role that the biological research centers have played in policy formulation has not come from direct involvement in policy research. Rather, in the process of developing new technologies for specific areas, both social and particularly biological scientists from the centers have engaged in continuous discussion and exchange of ideas with those responsible for policy formation. This is a natural product of the collaborative work of the centers with national scientific

programs. Both the need for and the effectiveness of such activities are greater when the adoption of relevant technologies is being impeded by constraints that would be amenable to release through modifications to policy. A strong collaborative scientific effort that is generating potentially significant advances will often form the basis for discussions, albeit of an informal nature. When the magnitude of potential gains in production or productivity is appreciated, and the distribution of the costs and benefits understood, policy makers become increasingly aware of the costs imposed by, say, inadequate access to inputs, lack of processing, or subsidized imports. For example, adoption of a new technology may be impeded by trying to force the use of certain inputs through restrictions tied to credit. Once the magnitude of the potential gains is established, the new technical possibilities can lead to a change in credit policy.

The existence of fertilizer-responsive varieties has increased the derived demand for fertilizers and led a number of Asian countries to allow greater imports and to foster domestic production in order to capture more fully the potential gains in output offered by the new technology.

The same argument applies to irrigation. The returns to investment in irrigation schemes are enhanced by the presence of high yielding rices and this change in the technical possibilities induces changes in the public irrigation policies. The existence of new pasture species which raise the productivity of marginal acid soils increases the returns to investment in roads and induces changes in the policies toward investment in infrastructure.

The presence of a new technology for processing cassava is leading to changes in Colombian public investment with the establishment of pilot

processing plants and plans for over 300 plants involving capital investment of US$3 million per year for five years.

The rate of these induced changes in policies may be accelerated by specific research studies undertaken at the centers, and by engaging in direct discussion, as in the case of the policy seminars conducted by CIMMYT. These were linked strongly to CIMMYT's work in generating new technology by being focused on what do policy makers need to know about farms and farmers in order to facilitate the development and use of improved technologies. Seminars organized on a regional basis were held in the Philippines, Colombia, Bangladesh and the Dominican Republic. The skills of outside specialists were enlisted, and case studies presented on public policies related to agriculture.

Evaluation of returns to research

Another channel through which the centers have had an indirect influence on policies is through studies that evaluate the return to research. These are of two types.

In the first type, estimates are made of the expected returns to research at a center that is either planned or underway, but has yet to have an impact on production. In the second, measurements are made of the economic returns to past investment in research and the distribution of any net benefits is examined.

The first type of study is aimed at improving the allocation of research resources within the centers themselves in order to increase the productivity of research, i.e., to ensure that the maximal amount of new and relevant

knowledge is generated by a given amount of research resources. To the extent that the centers are effective in doing this, there may be two indirect effects of relevance to the national programs. First, greater productivity from the resources available to the centers should allow wider and more effective collaboration with national programs and may help them by enhancing the productivity of national research programs which, in turn, allows them to capture funds more successfully from bilateral and other international agencies. The second indirect influence arises from the demonstration effect of the use of analytical methods for assessing the payoff to research. For example, the interest expressed by the director of the Mexican agricultural research system in drawing on work on research project appraisal done by CIMMYT is evidence of this type of effect on research policy.

Much of the work on the expected payoff to research is logically for use within the centers - it is their research policy rather than that of national programs which is the primary target. Both IRRI and ICRISAT have made major efforts in this field, IRRI examining the payoff to research across different rice cultures, and ICRISAT examining the congruence between its research effort and that suggested by a broad range of agronomic, social and economic indicators. This work covered all the crops and the regions in the ICRISAT mandate. In its long-range plan, CIAT examined the expected rate of return to investment in each of the major crop programs. However, in general, the centers do not appear to have devoted as much systematic and sustained effort to research assessment as seems warranted.

The second major type of assessment study concerns the payoff to past research, based on actual costs and realized gains. This is important work in which the centers have undoubtedly underinvested. Not only would their own

claim on resources be strengthened by more vigorous documentation of the magnitude and distribution of the benefits and costs, but the demonstration effect for national programs could be potentially significant. Low and variable levels of funding have characterized many national research systems. Careful studies showing the returns to collaborative efforts, whether they be in breeding (as is the case of rice in Latin America and Asia) or research methodology (as in the case of on-farm trial work by CIMMYT in Panama), can provide information that should be valuable for formulating research policy in national programs.

Nutrition policy

Biological research can affect the supply of nutrients by the selection of commodities for study, and by improving the nutritional quality of a given commodity. The powerful effect of research on basic food staples, the essence of the CGIAR approach, on the supply of nutrients has been well documented. Concerns that the improved cereal technology resulted in a reduced supply of proteins in India were largely allayed by the work at ICRISAT. The centers' varying positions on nutrition were recently brought together in an IFPRI-organized Inter-Center conference on Nutrition and Agricultural Research (Pinstrup-Anderson 1984).

Given the changing views of the role of protein in alleviating malnutrition, and due to the trade-off between yield and protein content, it is now the stated policy of the centers to give only secondary attention to protein content. Implicit in this position is the argument that the cost of achieving unit increases in the total supply of protein through research is lower by focusing on high yielding and widely adapted varieties than through breeding for higher protein content or quality. Again, the work of ICRISAT in

quantifying these issues has been valuable for guiding national research policy and avoiding an excessive diversion of resources to the improvement of protein content.

Notwithstanding the critical comments on this topic in chapter 8, it is notable that CIMMYT has had a substantial (now dimished) program of research on quality protein maize. It appears that this has been an outstanding technical achievement, as varieties with enhanced nutritional value and equivalent yielding levels have been developed, and are currently released in Guatemala. This has been a difficult project, however, absorbing significant funds. Given the experience and analyses of other centers, it is not evident that the contribution to total nutrient supply (or intake by protein-deficient groups) is higher than it would have been had those funds been dedicated to yield-increasing technologies. Expenditures on nutrition-related research of this magnitude demand scrutiny of their expected contribution to nutritional goals relative to alternative uses of the funds. In this particular case, the CIMMYT strategy influenced the allocation of effort by the Guatemalan national program. Resources devoted to the testing and promotion of quality protein maize had alternative uses which conceivably, with the wisdom of hindsight, could have had an even greater contribution to nutrient supply. On the other hand, several countries that had initiated research on soft endosperm opaque 2 maize following the pioneering work at Purdue University reduced their activties and relied instead on CIMMYT-developed germplasm.

Input policies

Research done by IFPRI on irrigation in S.E. Asia stimulated considerable discussion in the Asian Development Bank and the Philippine National Irrigation Administration. Estimates of long-range investment

requirements are being used in planning by these institutions. The results of the study have influenced irrigation investment policy toward small-scale diversion schemes rather than the traditional large-scale reservoirs.

Also in the Philippines, research results from IFPRI about the impact of rural credit markets on farm output and incomes have been used in revising interest rate policy.

IFPRI's collaboration with Mexican analysts contributed to changes in the design of the crop insurance program for rainfed areas. A broader collaborative effort with the Interamerican Institute for Cooperation on Agriculture resulted in a conference on crop insurance involving analysts and policy makers from many countries. By the careful documentation of the theory and administration of crop insurance and of experience with schemes in a variety of settings, the conference papers alerted policy makers to many of the pitfalls, and have encouraged a number of countries to undertake careful evaluations before embarking on large and costly insurance schemes.

Research on mechanization done jointly by A/D/C and ICRISAT provided information for Indian policy makers in their decision on import policies for agricultural machinery.

Initial research by IFPRI on the costing and sequencing of investments in rural infrastructure has been completed, and the results incorporated in long-range planning by the state government in Andhra Pradesh.

Through collaborative work with the Bangladesh Institute of Development Studies, IFPRI has examined the role of food-for-work schemes as a mechanism

for developing rural infrastructure. This has led to a number of changes in the management of the schemes and a heightened awareness of the opportunities for using food aid to achieve a productive impact.

IFPRI's direct collaboration in Bangladesh has provided information for the government to restructure its fertilizer policies, devising strategies that could sustain an increasing trend in fertilizer consumption without the fiscal burden of subsidies.

Food subsidies

Subsidies aimed at lowering consumer prices are prevalent in developing countries. Both their fiscal and economic costs are often high. Research can contribute to better understanding of how to improve their cost effectiveness in addressing the needs of the poor while minimizing the fiscal costs, negative effects on growth, and disincentives to domestic food production. IFPRI has made a substantial investment in research on food subsidies with detailed studies in 12 countries. The largest single country study has been a collaborative project in Egypt. This work featured:

(a) collaboration with a national institute;

(b) close ties developed with policy makers at the ministerial level from the outset;

(c) IFPRI staff based in the country to maintain close contact and provide overall project supervision;

(d) a major collection of primary data from households covering food purchasing and consumption patterns in both rural and urban Egypt;

(e) a broad mandate that has covered the impact of subsidies on consumption and household income distribution, foreign trade and exchange, monetary and fiscal management, investment and agricultural production.

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FEATURE: COLLABORATION IN POLICY RESEARCH: FOOD SUBSIDIES IN EGYPT

In early 1980, discussions were held between Egyptian officials and USAID staff concerning the food subsidy scheme. Among the questions raised were

- What are the full economic costs of the scheme?
- How widespread is access to rationed and subsidized food?
- How are household consumption patterns affected?
- What are impacts on farm households and their decisions about consumption and production?
- What are the effects on foreign trade in the subsidized products and other products?
- Who really benefits from food subsidies? Where do the costs fall?

A project design team was appointed by USAID, and IFPRI was invited to participate. The team developed a research proposal during a three-week visit to Egypt and, most importantly, established contacts with many key Egyptian officials. They included the Deputy Prime Minister for Economic Affairs, the Deputy Minister of Economy, Deputy Ministers of Agriculture and Planning, the Minister of Health, the Director of the Institute of Nutrition, the Director of the Institute of National Planning as well as senior professors at the University of Cairo. These contacts provided a basis for longer term collaboration by involving national policy makers from the very start. They also gave the team the chance to discuss the possibility of collaboration in the actual research with a number of institutes and universities.

In late 1980, letters of agreement were signed with the Institute of National Planning and with the Deputy Minister of Economy. This signing came only after visits by IFPRI's director, project leader and the IFPRI researchers nominated for the project. Two of these researchers had previously undertaken research related to Egyptian agricultural and trade policies. Further discussions were held in the Ministries of Agriculture and Planning, and with the Institute of National Planning. The Deputy Minister of Economy proposed that all contacts with other ministries should be channeled through his office, and this greatly facilitated the contacts with the Ministries of Planning, Investment and Economy, all of which were under the direction of the Deputy Prime Minister for Economic Affairs. Contacts with the Ministry of Supply were strengthened; these proved to be valuable throughout the project, as this ministry plays a key role in the acquisition and distribution of food.

From February 1981 until August 1982, two IFPRI staff members were resident in Egypt receiving logistic support from the Cairo Office of the Ford Foundation. Through a research contract with the Institute of National Planning, a major household survey was conducted covering 3000 households in rural and urban areas of the country.

Following the assassination of President Sadat in 1981, changes were made in the top echelons of government. However, the project had established a wide network of contacts and had sufficient support to survive the political reshuffling with no serious setbacks.

In September 1982, the major analysis commenced in Washington and constant contact was maintained with key ministers and deputies. Drafts of

reports were sent to them at every stage. By July 1983, major pieces of the project were largely complete and the project leader and the three senior researchers visited Cairo for a series of seminars and workshops in the Institute of National Planning. A full day presentation by the project team allowed for discussion of the methods and findings with over 60 people from the Egyptian and expatriate research community and key policy makers. This was followed by a series of private meetings in the offices of the Ministers of Investment and Foreign Cooperation, and Economy; the Deputy Minister of Irrigation and the Under-secretaries in the Ministries of Supply and Agriculture. These small meetings of one to three hours each with the team were conducted in a frank and open manner, and focused on the implications of the findings for a wide range of policy questions related to the food economy of Egypt.

These meetings reflected the interest of the policy makers in the study engendered by the long series of personal contacts that had been made over the preceding three years. The questions being addressed were known to the ministers and deputy ministers prior to the analyses, often having been suggested by them. During these meetings, the policy makers made further suggestions about presentation and further analyses. They were particularly anxious to use the series of studies to make projections about likely outcomes of possible policy changes. Such questions included the linkage between subsidies and wages, alternative methods for targeting, and the distributional consequences of changes in subsidy policy. Further discussions with USAID staff and visits to Cairo and to Washington by Egyptian officials led to a mutually agreed set of policy analyses that were undertaken at IFPRI. The results of these were, in turn, discussed in Cairo by IFPRI staff.

In summary this project has served to highlight several elements essential for effective food policy research. These include:

- the long gestation period required to build a base of confidence and collaboration with national policy makers and researchers;
- the use of a core team of senior, experienced food policy analysts;
- the importance of primary data collection;
- the need to examine many facets (agricultural and fiscal policy, monetary policy and exchange rates, foreign trade), in order to address adequately policy questions related to the food economy of a developing country;
- the need for constant contact with senior officials;
- the contribution to training, to project supervision and to goodwill and confidence that comes from resident staff;
- the role of seminars, workshops and private meetings for ensuring that the results and limitations are clearly understood by the policy makers;
- the flexibility to be able to respond to their suggestions and to conduct follow-up analyses addressing policy alternatives raised by them.

END FEATURE

An immediate and significant contribution of this project was to provide, through a series of publications, a more accurate, timely and comprehensive view than had been previously available of one of the world's largest food rationing and subsidy schemes. Because of its magnitude, the Egyptian subsidy program has attracted much attention and criticism, the latter not always well informed. IFPRI's findings have provided a more solid factual base for assessment of the scheme than had been available. This has been of value not only in Egypt but for all those concerned with the design, funding and execution of subsidy schemes.

At each stage in this project, close contact was maintained with senior officials and seminars were held to discuss preliminary findings, to guide future plans and to present the final results. A measure of the usefulness of the work to policy makers is their requests for additional research and for estimation of the implications or specific options of policy changes identified in conjunction with the researchers. The results of these efforts formed an integral part of the debate about future strategies. As noted, the contribution of an international center to policy making by a national government is to be judged not by the adoption of its recommendations but by the new knowledge which research contributed to national debate and policy making. IFPRI has attempted to ensure that this contribution has been made in the case of food subsidies through its workshops and conferences. In particular, the bringing together of outside analysts and policy makers to share the experiences of over 10 case studies with a broader set of countries has been an effective mechanism for communicating the results of IFPRI research, and providing a forum for exchange between policy makers and researchers.

Food trade and security

In May 1981, the IMF introduced a cereal import facility, designed to provide assistance to low income countries faced with abnormal food import bills arising from either poor harvests or high world prices. In 1975 Professor D. Gale Johnson had proposed extending the concept of crop insurance to developing countries, with financial support coming from the USA. Researchers at the World Bank extended this approach to cover both variation in domestic harvests and world prices, and to base the support on a multilateral basis. This was the essence of what became the cereal facility. IFPRI collaborated in the subsequent analyses with the World Food Council, IMF and FAO, and through a careful and balanced analysis, played small but useful role in the establishment of this new instrument. Of particular significance was the co-sponsoring (with CIMMYT) of an international conference on food security to present research results to policy makers from key international organizations. From this grew the further debate and analyses which led to the creation of the facility.

A country's trade policy affects both its ability to meet short-run food needs but also the incentives for long-term growth in food production and for export earnings from both the farm and non-farm sectors. IFPRI's research has established the significant effect of the foreign trade regime for agricultural production, intersectoral resource allocation and income distribution. This had heightened the awareness of policy makers of the potentially depressing impact on agriculture of commercial and exchange rate policies, and the interaction between food and other policies.

11.3.3 Research capacity

An important contribution of research on policy in the CGIAR comes not only from its direct impact on policy debates, but from its contribution to the domestic research capacity of national institutions. Given the importance of the agricultural sector, and the widespread ramifications of agricultural policy, there are potentially very substantial gains from improving the capacity for policy analysis within the developing countries themselves. It is generally true that most countries have underinvested in this area in the past, and efforts by the CGIAR system in general, and IFPRI in particular, are of value. Policy makers can make "errors" that have far reaching consequences. Such errors affect the efficiency with which a nation's resources are used, they alter income distribution, sometimes in unintended directions, and they can constitute a constraint to agricultural output. It follows that steps taken to improve the domestic capacity for policy analysis, and to enhance the quality of the information about alternative strategies to which policy makers have access, can lead to widespread and significant gains.

It has become increasingly recognized that general economic policy may be as important as policies directed specifically to agriculture. A policy of supposedly favorable producer prices may be completely nullified by other policies that overvalue the exchange rate; monetary policy can lead to negative interest rates, with consequent distortions on capital investment and employment growth. Given these sorts of ramifications, it follows that, if improved capacity for agricultural policy making is sought, the audience for information about policy analyses should comprise economic, social and agricultural policy makers.

For these reasons, IFPRI especially has established a wide network of collaborators in ministries of planning, economic policy, development finance and trade, as well as with central banks, producer organizations and universities. These contacts are in addition to work with other international agencies such as UNDP, FAO, WFC, UNCTAD, IMF, IBRD and other centers. Collaboration is facilitated through seminars, study visits and publications and, for instance, IFPRI's research reports have established a reputation for rigor and clear presentation. They often represent a distillation and synthesis of research methods as well as their application to a relevant policy problem. They are being increasingly used in graduate teaching, contributing to the formation of human capital for food policy analysis.

11.4 Coda

* In the past two decades, food production has increased substantially. Even in years of poor harvest, the global supply of food energy has exceeded the arbitrary levels of average per capita requirements by a significant margin.

* The gains have been unevenly distributed across countries and regions, and through time. The contribution of new agricultural technology has been uneven and the rate of growth of food consumption has been much lower and more variable in some countries than in others.

* It is increasingly clear that greater food production is neither a necessary nor a sufficient condition for a given country to improve either the level or reliability of food consumption.

* To understand and influence the level of food consumption requires attention to the economic, political and institutional setting as well as the technological circumstances. Research that leads to a better understanding of the nature and role of both domestic and international policies, and helps alleviate the constraints that they impose is an important element of global agricultural research.

* Food policy analysts face a complex set of interrelated issues including the generation and diffusion of new technology, the enhancement of physical and human capital, the distribution and pricing of food, and the role of trade and international policies.

* Questions concerning the design of technology are sometimes limited to the agronomic options. In many cases more effective and direct solutions may be achieved with changes in policies far removed from genetic and agronomic considerations. For this reason the CGIAR has sought to integrate the social sciences with the work of the centers. While the individual centers have adopted widely differing methods of achieving this, the primary focus has been on enhancing the understanding of the economic and social circumstances of producers and using that information to guide the development of new technology and institutional changes.

* Over two-thirds of the total social science research in the CGIAR is conducted within centers other than IFPRI. But there is a risk that analyses of policy issues may become sporadic and piecemeal, lacking depth in analytical capacity, access to information, and experience in policy issues. Furthermore, many issues such as commodity and trade policies cannot be adequately addressed from within the centers. For these reasons

IFPRI represents a small but crucial link in the research on agricultural and food policies.

* The generation of new technology itself fuels continuous debate about national policies that may impede its diffusion. The scientific staff of the centers have played an important role in creating greater awareness of the need for policies that allow the benefits of new technology to be realized.

* Considerable care is needed in attributing policy changes to the work of the centers. Quite apart from the difficulty of identifying new or changed policies and tracing their impact, any such attribution might well be construed as trespassing on national sovereignty. However, it is evident that such efforts as CIMMYT's policy seminars, and research at IFPRI on input policies, food security, crop insurance and food subsidies, have all contributed to a more informed debate and been in demand from policy makers.

* The contribution of policy analysis comes not only through its direct effect on policy debates but also from its contribution to domestic research capacity. Many countries have underinvested in this area in the past and the efforts of the CGIAR system, and of IFPRI in particular are of value in providing much needed information about it.

* Many of the policy issues affecting food and agriculture fall in the area of general economic policies, be they trade or exchange rate policies, monetary or fiscal policies, or others. For this reason the centers working on food policy must continue to foster a range of collaborators in

ministries of planning, economic policy, trade and finance, as well as with central banks, universities, producer organizations, and international agencies.

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PN-AAZ-939

INTERNATIONAL AGRICULTURAL RESEARCH CENTERS:

ACHIEVEMENTS AND POTENTIAL

Part IV

A Study
Directed by Jock R. Anderson

Draft of August 31, 1985

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Part IV ISSUES

Overview

This Part diverts from the main thrust of examining collaboration with and contribution by the international research centers to considering several important research issues related to the future impact of the centers. The list is a partial one and somewhat idiosyncratic in coverage. The CGIAR system as a whole rightfully can be considered as the largest systematic plant breeding operation that the world has ever seen. Beyond what has been reviewed in chapter 6, other achievements in this field are not addressed head-on, because it is typically a central aspect of the quinquennial or external program reviews to be concerned with the plant breeding work. Some related aspects, however, are taken up in chapter 12 concerning germplasm such as exploration, conservation, evaluation, enhancement, etc. This leads naturally to chapter 13 with its broad consideration of centers' work in relation to the protection of plants from pests, diseases and weeds.

The next chapter concerns the development of tropical lands. Many tropical lands are inherently fragile whether they be (a) presently under dense rainforests in the wetter areas, (b) more stable soils but in erosion-prone situations or (c) more semi-arid environments. Since many of the problems of concern to agricultural development in the tropics are not only challenging but also inherently sensitive, there are important policy issues to be addressed as to the desirability or otherwise of developing tropical lands, even when they may be sorely needed for expansion of agricultural activities in the face of growing population pressures. In some cases, it is demonstrably socially short-sighted to farm such lands since their period of useful productivity is short, especially when the traditional resting period

of regrown natural vegetation is squeezed through ever-more intensive exploitation. Governments must be alert to the importance of long-term, sound and sustainable ecological management of what may be essentially irreplaceable resources. Several of the centers (but especially two of them) have been engaged in activities of relevance to tropical land development. Other pertinent issues which the centers have not yet been able to address are also noted here.

A research policy issue of emerging importance concerns the degree to which new technologies can and should be adapted and developed for specific environments. The early successes with reduced plant stature and daylight insensitivity of wheat and rice germplasm led many research workers to a belief in wide adaptability of plant material as the most cost-effective strategy in plant breeding and technological development in general. Recent experience, backed by growing worries about the plant breeding issues raised in chapter 6, is contrary to this earlier belief and there is now a more active concern for a more appropriate "targeting" of technologies and genetic combinations to the needs of specific environments, especially where these can be associated with groups identified as the most needy recipients of new technologies. The issues here (chapter 15) also relate to the degree to which it is possible to classify and describe the diverse edaphoclimatic (i.e., soil/climate) environments of developing countries.

Closely related to this question is the important work that in more recent times has been referred to as farming systems research. Amongst the essential features of this research is a primary concern for the economic viability and growth of particular groups of farmers and the generation of technological changes appropriate to their circumstances and objectives. The

farmer, farm family or the larger household is put virtually on the pedestal of decision making and, in understanding the objectives of the decision making unit, technologists and others such as social scientists endeavor to shape a technological development that will be perceived to be more appropriate for those who are influenced by it and, in due course, actually will be more effective in realizing the complex ambitions of advancement. Unfortunately, the terminology has become rather clouded, and many diverse activities both within and without the centers are currently described as being within the realm of such work. These issues are raised, reviewed and distilled and conclusions drawn as to an appropriate stance for international institutions in this work as well as to their relevance and effectiveness in it. Certainly there is universal agreement that such work is a multidisciplinary activity and that the centers, in being prominent in demonstrating effective transdisciplinary cooperation, have played an important role as exemplar for others who are often supported through bilateral assistance in similar work.

The next set of issues addressed concerns the appropriateness or otherwise of research directed at enhancing the efficiency and exploitation of machines in agriculture. The centers have had relatively minor involvement in mechanization research but several at various times have had significant engineering activities, and these are critically appraised with a view to drawing more general conclusions as to the desirability and utility of work that increasingly must be scrutinized in situations of excess labor supply.

A rather different set of issues is to be addressed in chapter 18 concerned with the centers' work on biological fixation of nitrogen, mainly through Rhizobium associations with legumes but also some work with Azolla associations. Work on biological nitrogen fixation (BNF) is important in its

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own right in connection with rising costs of energy, and thus of nitrogenous fertilizer manufactured from petroleum feedstocks, as well as of potentially critical significance to resource-poor farmers with inadequate access to purchased inputs, especially manufactured nitrogenous fertilizers. To the extent that it is possible to develop "appropriate technologies" that do not depend on such energy-intensive manufacturing, the work may prove to be of great significance in agricultural evolution.

A purely retrospective view of impact is surely incomplete. Accordingly, an attempt is made in chapter 19 to catalog the major "pipeline" innovations that are in prospect in the system. For selected major innovations, consideration is given to the likely pattern of adoption and some economic dimensions of impact.

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12 PLANT GERMPLASM WORK

12.1 Introduction

Some of the more readily measured, and demonstrably most important, impacts of the centers' and their partners' work in germplasm utilization and plant breeding are described in chapter 6. The intention in this chapter is to take a more center-centric view, and to focus more on the several steps involving plant germplasm that are anticedent to the production of advanced lines and varieties. A more comprehensive discussion of most of the issues broached here is available in a companion paper (Hawkes 1985).

12.2 A Scheme for Overviewing the Work

Systematic efforts in plant germplasm work are longstanding, and the centers are relative latecomers to the field. Accordingly, a logical first step in reviewing their activities is to assess the extent to which prior work has been surveyed for its guidance to further activities. Surveys are appropriately broad in concept ranging from consideration of uncollected materials in nature through assessment of the state of existing collections, including correction for duplication between and among collections, to their geographical/ecological scope and physical/biological aspects of their storage.

A central aspect of germplasm work is exploration and collection. Along with others, the centers have been more or less active in the work and, in the crop by crop account of section 12.4, this is the second aspect on which comment is made.

The third consideration in the scheme is conservation. A genebank is, barring regular and risky regrowing of the collection, only as good as the quality of the storage. Long-term safe storage is now technically feasible but gene banks are by no means uniform in this respect.

Evaluation is the fourth broad activity considered. This consists of characterization, screening, description and recording, preferably under diverse ecological circumstances.

The next activities to be noted are more directly concerned with plant and crop improvement - namely, germplasm enhancement whereby particular genes are actively exploited through crossing, breeding trials whereby diverse germplasm is examined in different ecologies, and ultimately varietal release with its economic consequences (chapter 6).

Other aspects considered as appropriate to complete the scheme are training, the state of the centers' various germplasm data bases, and the quality of any research per se on germplasm matters.

12.3 World Germplasm Activities and the Contribution of the CGIAR System

A major achievement of the IBPGR in its first decade has been to contribute to an increased awareness that genetic variation stored in cultivated crops and related wild species is an important natural resource.

It is now widely recognized that processes are accelerating that threaten the continued existence of some of nature's diversity. Traditional varieties (land races) are replaced by improved and often uniform varieties. Exploitation of forests, unchecked soil erosion and other consequences of human interference are taking their toll (see also chapter 14).

The effects of plant breeding are often antagonistic to the maintenance of genetic variation even though the latter is its basic resource. Agricultural development requires increased yields, and this has traditionally been achieved by selection which has inevitably led to increased uniformity. Second, as environmental factors are better controlled (soil fertility, irrigation, disease and pest management), selection objectives are more closely defined, emphasizing productivity, quality and certain resistances effective over wide geographic areas. Close definition of generally valid selection objectives had led plant breeders to the use of often restricted gene pools that currently already satisfy many of the basic requirements. New characters are introduced as required. However, this is usually done through methods of crossing, minimizing changes in basic genotypic structures in the population or the recipient cultivar. Hence genetic resources are primarily

seen as a source of identifiable characters and only seldom as a source of increased overall genetic variation.

The IBPGR recognizes that its primary task is not usually direct action but rather encouragement of genetic resources conservation, documentation, evaluation and utilization. However, the Board has had to take direct action in some situations. The Board is not primarily a technical assistance agency nor a funding agency for all genetic resources work. Rather, its work is conceptual and catalytic, and is evolving towards increased intellectual leadership through research, development of documentation techniques and training. It has encouraged development of networks of base collections and of national genebanks for its numerous crops rather than building and operating genebanks.

IBPGR works with more than 100 countries and almost 600 separate institutions in both the developing and industrial countries, concerning genetic resources of more than 100 crop species and several groupings of crops (e.g., forages which comprise dozens of species). IBPGR runs no genebanks, it controls no genebanks, it gives orders to no one. Except for its financial resources to assist, it has no power but persuasion.

The Board strategy has been one of involving a broad segment of the scientific community in its planning and cooperative programs. Hence hundreds, perhaps even more than a thousand scientists and technicians have been or are involved in the Crop Advisory Committees, Working Groups,

workshops, planning meetings, training courses, collecting missions and other activities. Most serve enthusiastically and without remuneration.

Among crops, the Board's priorities rest on the four criteria: (a) risk of genetic erosion, (b) economic and social importance, present and potential, (c) plant breeders' requirements and (d) size and scope of existing collections. The priorities in the first decade included food crops, oil seed crops and a limited number of industrial and minor crops and fuelwood trees in arid areas. In the early 1980s, some major fruits were added and, in 1982, forages. Regional and minor crops were supported in some circumstances, but in general, they were considered the task of national programs or other organizations. As collections began to be completed in certain crops, they decreased in priority.

A recently published summary (IBPGR 1984) of the first 10 years of collecting activity stimulated by IBPGR has listed seeds of 138 crop species that have been deposited in genebanks. These have come from over 300 collecting missions in 88 countries in all parts of the world. Over 550 collectors have been involved, the majority of whom came from developing countries. The resulting material was placed in genebanks in more than 450 organizations in 91 countries, well over half of them being developing countries. Genebanks now have substantial collections of most major crops as well as material from many other important crops. Rough estimates have been made by IBPGR staff, curators and others on the amount of genetic variation collected (Table 12.1). The percentages should be interpreted as rough

Table 12.1 IBPGR-estimated number of accessions for some of the main food crops and percentage of the total variability collected

	Accessions in major genebanks	"Distinct" accessions	Degree of comprehensiveness Landraces	Wild Species	Threat to material in the field
	thousand	thousand	percent	percent	
Wheat	400	125	95	60	medium
Rice	200	70	70	10	medium
Maize	70	60	90	n.e.[a]	-
Barley	250	50	40	10	medium
Sorghum	90	20	80	10	high
Phaseolus	65	33	50	10	medium/low
Groundnut	33	10	70	50	low
Sweet potato	8	3	60	1	high
Potato	42	30	95	n.e.	low
Okra	3	2	80	3	medium
Cowpea	18	12	75	1	high

[a] n.e. denotes not estimated.

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estimates of what can be considered as "adequate" collections of the various crops.

It is believed that a large amount of the genetic diversity of the major crops has now been collected. Many countries have been involved and local resources have been employed as much as possible. Learning about existing gaps remains an important task. In order to identify gaps and fill them, a knowledge of genetic diversity already represented in the collections is necessary, through characterization and evaluation of these collections. Knowledge of what remains in the field in centers of crop diversity requires assessment of genetic diversity within those centers and of collecting strategies needed to sample best that diversity.

Base collections are those which have the capability of long-term storage. An active collection, in contrast, is used for regeneration, multiplication, exchange, evaluation and documentation. A base collection must be closely associated with an active collection since base collections do not usually become involved in germplasm exchange. This is not well understood, and misunderstandings have led to unwarranted charges of restrictions on the free flow of germplasm.

Another point often misunderstood is that the "global network" of IBPGR consists of base collections only. Also, not all genebanks with long-term storage capacity have been designated as base collections by IBPGR. The designation as a base collection is made by the Board according to its

strategy that, for each major crop, there should be at least one center, preferably two, designated by the Board, which accepts responsibility for holding a base collection of materials under conditions assuring their long-term viability.

The Board, aided by worldwide advice from its Crop Advisory Committees and Working Groups plus staff and consultants, considers that about 50 base collections are needed to form a reasonably complete network that will cater to the needs of some 40 crops or groups of crops. The Board expects the target of 50 base collections will be completed by 1986 and that by 1990 all those base collections will have been duplicated. IBPGR, more than any other single agency, or group of agencies, has salvaged the major part of the world's crop germplasm. But more work is needed in respect of wild species related to the crops themselves.

The problems of seed storage under conditions favourable to long-term conservation and minimal loss of the genetic integrity of the original samples have been addressed. IBPGR's scientific promotion for the storage of orthodox seeds is excellent. IBPGR has also turned its attention to recalcitrant seeds; these are seeds that cannot be stored by techniques in which temperature and humidity are reduced. The solution lies in the field of *in vitro* storage of meristems rather in storage of the seeds themselves. The organization of international efforts in the field of *in vitro* conservation has been chiefly concerned with the conservation of clonally propagated materials and species where seed storage is either difficult or impossible.

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12.3.1 Use of data and new descriptors, and creation of global networks

IBPGR has placed considerable emphasis on documentation and computer storage of information on existing germplasm collections. Assistance with the purchase of "hardware" has been provided for 22 countries, mostly in the form of microcomputers. Although much effort and financial support has been provided in this area by IBPGR, the results have been mixed. A steady flow of data into the data base systems and out again when requests for information are received, is still not attained in most countries.

In section 6.4 the question was raised of the importance of interactive geneotype - environment effects in diverse socio-agricultural environments. If these effects are judged important, they have implications for germplasm conservation work. At the point of collection, it would be posible to record information on two kinds of socio-agricultural components of GE effects: end uses and husbandry descriptors. An exmple of the first would be whether or not sweet potato or cassava leaves were being used and, if so, whether fresh or dried, as a vegetabele. Examples of the second would be the ancient Hopi (N. American) practice of planting a certain maize variety 12 inches deep to avoid drying winds in an area where annual rainfall may fall to four inches; the storage technology used for a particular cassava variety for up to 18 months above ground, in Luapula Province of Zambia; or the intercropping of compatible maize-climbing bean varieties. Descriptors of these kinds have not been recorded and are inherently unlikely to be observed in laboratory tests or in planting art. IBPGR could take the lead in identifying and developing field recording of these kinds of descriptors.

National genetic resources programs have been established in 83 countries, of which 50 were assisted or stimulated by IBPGR. National committees have been created in about 25 countries. Its work is chiefly concerned with coordination of country activities, exploration, conservation and training. Regional coordinators have been appointed for Europe, Latin America, W., E., and N. Africa, S.E. Asia and the Middle East. Some regions are much more advanced than others. S.E. Asia and Europe are examples of good cooperation, whilst S.W. Asia is an area where many difficulties have been encountered. Latin America, W. Africa and E. Africa are just in the initial stages.

12.4 Centers' Activities by Crop

12.4.1 Wheat

Wheat and wheat relatives have been collected by expeditions from many different countries and are stored in gene banks in various parts of the world. IBPGR (1981) is the first published attempt to study what materials in national and regional gene banks and where collections should still be made. Further collecting still needs to be done, particularly in N. Africa, S. Europe and S. USSR. The impetus here comes from IBPGR. CIMMYT has had no apparent influence but ICARDA in 1984 collected durum wheat and barley in Morocco with IBPGR.

Wheat collections are held in 40 different countries, 24 of them developing. The CIMMYT wheat collection is largely a breeders' working collection. The composition of the bank is approximately, in percent:

materials derived from land races, 15; developing country varieties and other advanced lines, 50; industrial country varieties, 4: wild species, 5. This is, therefore, not a germplasm bank in the usual sense, and the small proportion of land races and wild species militates against a proper use of these resources in the plant breeding program. The genetic base is narrow, even though it is most effective for short-term advances. Thus, in a wider long-term sense, it must be difficult for CIMMYT to make effective use of the total world wheat genetic diversity.

The ICARDA position in respect of durum wheat is a little better. The 16,412 accessions of durum wheat consist mainly of land races, a large proportion being from high elevation sites. More samples need to be banked. The genetic base is a satisfactorily broad one and, when storage facilities are complete and material is moved, the effects of the work should be very positive.

A wide crossing program started at what is now CIMMYT in 1959, the work was targeted towards resistance to Helminthosporium sativum, Fusarium gramineum and stress tolerance to salt, drought, heat, aluminum and copper. Crossing success has been low, with much autosyndetic pairing in the F_1s. Some 27,000 lines from these crosses have been evaluated, however, and some promise is shown. Little use has yet been made of bread wheat land races. The cereal breeders at ICARDA have begun a wide crossing program using durums, Triticum dicoccoides and T. aestivum.

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CIMMYT's wide cross program has the purpose of introgressing useful genes from related genera to wheat. To date, 188 intergeneric crosses to wheat have been accomplished since the revised wide cross program was initiated in 1979. The intergeneric crosses together with germplasm from CIMMYT's recently expanded interspecific crossing program should serve the variability needs for a very long-term wheat breeding program. to assist in the introgressing of genes from related species and genera, CIMMYT has collaborative projects underway in Australia, United Kingdom and the United States, with research institutions that are on the cutting edge of science in the development of new biotechnology.

The benefit derived from wheat-breeding research is described in chapter 6. Training in evaluation, breeding and trial work has been intensive and has provided major accomplishments in the development of national programs and in the correct utilization of CIMMYT and ICARDA breeding lines. Satisfactory data-base systems have been developed at ICARDA, but the CIMMYT data-base system started very late and inventories are not yet available.

CIMMYT can be criticized for its lack of interest in surveys and exploration activities, for its to apparent reluctance to accept global responsibility for bread-wheat germplasm (through its interpretation of its present mandate), and the rather narrow genetic base of its gene-bank material. This latter may result in a program with too narrow a genetic base. Nevertheless, CIMMYT's record for the breeding and release of varieties in cooperation with national programs is spectacular. However, it may well be

difficult to maintain this much longer if the genetic base of the CIMMYT collections is not considerably broadened. CIMMYT's gene bank should perhaps be more "active" and not confined almost entirely to "working": it should possess a broad genetic base of land races and wild species of wheat, Aegilops and related genera. ICARDA's record in this respect is better, but the gene bank activities need to be sped up greatly.

CIMMYT has a strong program underway in the development of the man-made crop, triticale, a product of wheat x rye cross. Triticale is destined primarily as a food and feed crop for areas not generally suitable for wheat or maize such as acid soils and arid and semi-arid regions. Since the inception of triticale research at CIMMYT in 1968 the crop has been changed form that of a scientific curiosity to a useful crop. Tunisia, Brazil, Argentina and several other countries are now increasing their triticale hectarage. Poland hopes to have in production 1,000,000 hectares of triticale by 1990. Variability for triticale by 1990. Variability for triticale breeding is limited but recent improvements in biotechnology have greatly enhanced the number of wheat x rye combinations being made which will quickly broaden genetic variation in triticale. CIMMYT is maintaining a germplasm collection of spring triticales in Mexico. Practically all known spring triticales are included.

12.4.2 Barley

Neither CIMMYT nor ICARDA has undertaken a survey of materials in the field and in the gene banks (they rely on IBPGR for this function), but IBPGR and ICARDA assembled data on world barley expeditions and concluded that

Ethiopia and Turkey were fairly well-collected (excpet for further "inland" collections in Ethiopia), whereas other countries were either poorly collected, or there was little information on the collections, e.g., China. Only 12,000 land race and wild species collections have been made, of which more than one third are from Ethiopia and more than 10 percent from a single expedition carried out in Greece, Turkey and Iran. Further barley collections should be made in the ICARDA mandate area of N. Africa and the Middle East. Special areas to search are the Atlas mountains and other mountainous areas, desert oases and wadis.

In the 1984-85 season, ICARDA collaborated with IBPGR in a collecting mission to Morocco when 89 samples of barley were collected as well as other crops. ICARDA should make itself responsible, either alone or with IBPGR, for a crash program of barley land race and wild species collections, since otherwise, not only will much genetic diversity be lost, but even if it is not, it will be unavailable to breeders. CIMMYT has a breeders' working collection of 4630 barley accessions, ICARDA possesses 14,215 accessions, mainly obtained from the USDA small-grains collection. Storage is only medium-term at present.

Some 8000 accessions have been characterized at ICARDA using 25 descriptors, all but two being morpho-agronomic and the rest dealing with protein and lysine content. Most screening is presently done in the field. Drought resistance is extremely important and land races from China, Tibet and Korea have been evaluated for this character, as well as some from

the Middle East and 780 accessions of H. spontaneum. Salt tolerance is also of importance and 69 barley lines have shown promise for salt-drought tolerance. A preliminary catalogue for 5000 accessions has been produced. Little germplasm enhancement is done but, perhaps with barley, it is unnecessary when using H. spontaneum and land races for problems of barley production in the Middle East. Conventional barley breeding using European and American breeding lines and cultivars is not very useful in solving problems of drought and salt tolerance in the ICARDA mandate areas. Varieties are needed that are able to yield in regions of low rainfall (180 to 325 mm/yr) or where green-stage grazing by sheep is possible (dry stubble is even more important). Testing at seven sites and with the usual types of nurseries (including key-location disease nurseries) in Lebanon, Syria, Tunisia and Cyprus has shown that a number of land races and selections from them show considerable promise.

The ICARDA genetic resources unit (GRU) was formally constituted only in 1983 to replace and coordinate the previously somewhat haphazard accumulation of germplasm within the crop programs, so it has not done too badly in respect of barley germplasm. Effectiveness, while still small, should be improved when a cereals liaison officer is appointed, and when the genetic base is broadened.

12.4.3 Rice

The global mandate for rice genetic resources lies with IRRI. West African rice (both O. sativa and O. glaberrima) comes within IITA's mandate but is also encompassed within that of IRRI. Two workshops were convened

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jointly by IRRI and IBPGR to review the needs and priorities for rice exploration and conservation (IBPGR/IRRI 1978, IRRI/IBPGR 1983). The IBPGR/IRRI (1982) rice advisory committee reported on Asian wild rices, setting out priorities for exploration, conservation and characterization.

Rice exploration activities have been well coordinated and documented. Manuals for field collectors have been published. A coordinated exploration scheme involving fourteen countries in S. and S.E. Asia has been established by IRRI. An IBPGR exploration officer has recently been seconded to IRRI with a view to collecting from regions where inadequate numbers have so far been received. More than 8000 samples have been assembled from "stress" environments. From 1971-84, some 39,200 samples were collected in Asian countries, a little less than one third of which were obtained by IRRI expeditions. IBPGR grants enabled nearly 11,000 examples to be assembled from seven Asian countries and Madagascar. In Africa, coordinated efforts between IITA, ORSTOM, WARDA, etc. provided nearly 9000 samples, of which 872 were of O. glaberrima and 77 were of wild species.

Long-term base collections are held only at IRRI (global) and IITA and in the U.S.A. (regional), although major collections are held in a dozen other countries. An excellent program for rice storage and regeneration is in operation at IRRI (IRRI/IBPGR 1983), and there were just under 80,000 entries, in June 1983 including 1100 wild species accessions. The IITA collections of nearly 9000 entries are under medium-term storage, but only one half of the collections can be accommodated in long-term base storage conditions. A grant

received by IITA from the Italian government in 1984 will provide the correct conditions and capacity for base storage of rice and other crops.

IRRI's evaluation program includes not only characterization for 50 morpho-agronomic features but also for a range of 38 resistance and adaptation characters. IITA uses 44 morpho-agronomic characters and a range of pest and disease resistance features related to African conditions. In both institutes evaluation is very satisfactory.

The input of disease- and pest-resistant and stress-tolerant germplasm into rice gene pools, using a team approach is progressing actively (Chang et al. 1982). Introgression of useful genes from wild species into cultivated races can be valuable (e.g., resistance to grassy stunt virus from O. nivara). Green leaf-hopper resistance has been transferred from O. glaberrima to O. sativa through hybridization. The transference of aluminum tolerance from Brazilian to Asian rices and of iron toxicity resistance from African to Asian rices has also been noteworthy. The benefits of rice breeding research in the centers are described in chapter 6.

At both IRRI and IITA, training in genetic resources work and related disciplines has been good. Two courses have been organized at IITA financed by IBPGR. The gene bank at IRRI has provided 2-6 month in-service training on genebank management for staff of national research institutes. Both institutes have good programs of data storage and retrieval. Catalogues have been developed and requests for special information can be supplied.

12.4.4 Maize

Since maize is now grown in nearly all tropical, subtropical and warm temperate countries of the world, the problem of conserving its diversity is rendered more complex than that of a crop restricted to a smaller and more uniform area. The centers of diversity lie in Latin America. The CIMMYT maize bank, which contains most but not all the Latin American germplasm, has no computerized data storage and retrieval system from which inventories or computer-generated maps can be constructed. Such a data base should also incorporate information from the more important national maize collections in Latin America and, if possible, in other parts of the world. There is thus poor information about where collections should yet be made. The lamentable lack of impact here is due to the low priority set by CIMMYT in the past for this type of work, including the proper management of the maize gene bank itself. In November 1984, CIMMYT agreed to accept global responsibility for maize germplasm from 1985 onwards, and long-term storage and other facilities will be provided.

IBPGR has sponsored maize collecting expeditions in various parts of the world. Although it believes that world maize collections are adequate, apart from the Himalayas and a few other small areas, this will not be certain until the computerized surveys are completed. A great range of land race material has been collected in the past. It is to be hoped that this still exists in a viable condition in the banks. CIMMYT has a rather poor medium-term storage facility for 15,000 samples running at 0-3°C with a relative humidity of about 32 percent and a seed moisture content of about 11 percent, but planned

improvements should raise the storage life from 20-25 years to 40-50 years. All materials need regeneration, and this is being carried out cooperatively between CIMMYT and Pioneer at the rate of some 500 samples per year. At this rate it will take 20 years to complete. It has not been possible to regenerate 1200 of the original collections and 750 of them, which come from Ecuador and Peru, cannot be brought to the flowering stage in Mexico. The CIMMYT collection is basically a very valuable one. It should certainly be better stored and coordinated to give it greater potential impact. Some 30 maize populations are included in international testing. However, the effective use of wild maize relatives is less strong, and this aspect needs considerable improvement.

Characterization will progress steadily as material is regenerated. Apart from this, a great deal of evaluation has been in progress. Material has been assessed at different sites and, when found useful, has been taken into the enhancement program. Techniques of single mass inoculation have been evolved that can be used easily in developing countries. In addition, tolerance to stress conditions such as aluminum and cold tolerance is actively looked for in all the collections. Yielding ability is not considered to be of such importance, since it already exists in advanced breeding lines. The contribution of the centers to the genetic improvement of maize is discussed in chapter 6.

In summary, more wild material ought to be stored and evaluated, particularly a broad base of Euchlaena germplasm. Perhaps less effort should be devoted to very long-term activities, such as attempts at maize-sorghum

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crosses. Impacts are very strong on breeding, working with national programs and varietal releases. Finally, the recent decision to accept the global mandate for maize genetic resources should make it possible for an even broader maize genetic base to be evaluated and utilized within the next quinquennium.

12.4.5 Sorghum and millets

Sorghum and millet surveys were carried out by the IBPGR Advisory Committee on Sorghum and Millet germplasm in 1976 and 1981. On the basis of their priorities and recommendations, a world survey was published later (Acheampong et al. 1984). Good collections of cultivated sorghums exist, even though urgent work is needed in the Central African Republic and Chad. There is extremely poor representation of wild forms in the genebanks and, in 1982, only 167 collections belonging to 10 taxa were in the ICRISAT collection. Much more collecting is needed, especially in Ethiopia, eastern E. Sudan, Uganda, Burundi, Rwanda, Kenya and Tanzania.

Pearl millet is also under-represented in respect of wild materials, which are needed from Niger, Sudan and Burkina Faso. Cultivated and wild materials are needed from the Central African Republic, Chad, Mauritania, Namibia and Sierra Leone. The oases of N. Africa and certain areas of Ethiopia also need to be explored, as well as E. and S. Africa, parts of W. Africa, Burma, PDR Yemen, Spain, Pakistan and India. Both the cultivated species and progenitor materials of finger millet need to be collected as well as other wild species in the secondary gene pool, or even the tertiary one.

Very little collecting and other work has been done on the more minor related species, including foxtail millet, proso millet, little millet, barnyard millets, Kodo, Forio millets and teff.

A total of 24,604 sorghum collections are held at ICRISAT under medium-term conditions, and a new long-term storage facility at -18°C with capacity for 100,000 samples is almost completed. About half of the collection was taken over from the Rockefeller Foundation collection. A wide "range of genetic stocks is stored. Over 210,000 germplasm samples have been distributed. Large collections are stored also in Argentina, Australia, China, Ethiopia, ORSTOM (France), India, Mexico, Romania, Thailand, USSR, U.S.A. and Yemen A.R. Sorghum long-term security base collections agreed to by IBPGR are at ICRISAT and Fort Collins, U.S.A. Similar collections for Pennisetum are at Ottawa, ICRISAT and Fort Collins; for Eleusine at Addis Ababa, for Panicum miliaceum at ICRISAT; and for Setaria italica at Beijing, and ICRISAT.

ICRISAT stores 16,985 samples of pearl millet, again half coming from the Rockefeller collection and 1863 samples of finger millet, whilst the Indian national collection numbers about 6000. There are 1260 accessions of foxtail millet at ICRISAT and nearly 10,000 samples in China and India (possibly including duplicates).

ICRISAT's evaluation work on gramineae is confined to sorghum and pearl millets. The other millets are stored only, but IBPGR has provided funds for their characterization. For sorghum, 20,355 lines have been evaluated using

morpho-agronomic characters. Disease, pest and drought resistance has been recorded but merely on the basis of no attack or apparent adaptation. Screening against grain mold, downy mildew, Striga and midge has been carried out also. Large-scale pearl millet characterization and screening for resistance to downy mildew, ergot and smut has been undertaken, and 16,022 lines have undergone morpho-agronomic evaluation.

Attempts have been made to introgress genes from agronomically poor or wild material into a high-yielding short-stature and daylight insensitive background - the so-called conversion process. This has been accomplished both in sorghum and pearl millet. Since there is not a wide range of wild and weedy materials of either crop in the genebank, there has not been too much scope for such work. Sorghum and millet breeding research is discussed in chapter 6.

12.4.6 Potato and sweet potato

CIP accepted the global mandate for potato genetic resources when it was first founded. It does not conserve the cultivars of N. America, Europe, Asia and Africa, however. CIP has recently approved a program of research for sweet potato in specific aspects where CIP has a comparative advantage, whilst IITA previously accepted the total global mandate for this crop but, in practice, confines its activities to Africa. AVRDC has been allocated the mandate for sweet potato germplasm in Asia by its governing board. CIP has made a major impact in surveys and has moved much further than any of the other centers. Planning conferences attended by authorities from various

countries were convened at three-yearly intervals to establish priorities for countries, and for cultivated and wild potato species.

An IBPGR survey of sweet potato germplasm was published in 1981, and CIP has commenced a sweet potato survey for the Americas. Wild species are to be collected in the Americas particularly, since these are considered to be genetically closer to the cultigen. Wild species in other parts of the world (Africa and S.E. Asia, especially) ought also to be included so as to provide as broad a genetic base as possible.

By 1980, over 90 percent of the total cultivated potato germplasm had been collected, due to a crash program funded from the CIP core budget. This is unique amongst the CG system. Wild species have also been systematically collected, particularly in Ecuador, Peru and Bolivia, following the recommendations of the planning conferences. Collections in Argentina, Colombia and Chile were made with national funding, helped also by CIP and IBPGR. In Mexico, joint Mexican/USA/Canadian expeditions have added materially in recent years to the wild potato germplasm already present in several gene banks in the USA and Europe. Funding from F.R. Germany and the Netherlands has recently been provided, together with CIP support, to collect in Bolivia and Argentina. Some 1500 samples of wild potato germplasm have now been collected from Peru, and even more from Bolivia and Argentina together. Most of the Bolivian, Argentinian and Mexican collections were made by collectors not employed by CIP, but with full coordination with it. This is an excellent CIP record which provides strong impacts on activities further down the genetic resources chain.

IITA now has 1000 clones of sweet potato collected since 1976 in expeditions to 18 African countries. AVRDC, with help from IBPGR has established a very large collection (some 1,200 samples). Collaborative exploration work has been effected in Indonesia, Malaysia, the Philippines, Thailand and Papua New Guinea.

The cultivated potato collection at CIP consists of 5000 samples. These are grown annually at high altitudes in the experimental fields and are stored in a controlled conservation facility. Duplicates were eliminated with the help of a computer and checked biochemically in Germany (at BRD). In vitro storage has been developed, and currently 250 clones are being stored. The wild species collection consists of 90 species and 1500 samples, stored as true seed, together with seeds of the cultigens, in a medium-term store. The limitations in this work are the slow progress in producing enough true seed of wild species for storage, and the lack of response to requests for samples from outside bodies. The difficulties with clonal distribution are that virtually only in vitro, pathogen-free material can be dispatched. IITA holds 1000 clones of sweet potato in tissue culture. Superior clones from this collection tested to be virus-free have been distributed to 49 countries. It was agreed by IBPGR that AVRDC should be a clonal repository for sweet potato germplasm and its collection now consists of 1200 entries. Some 736 collections are also maintained in Papua New Guinea in a vegetative state.

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All the entries of cultivated potato at CIP have been characterized according to the agreed IBPGR descriptor list. There are 56 morphological descriptors, 10 agronomic ones, 5 for frost, drought and heat, 16 for diseases and pests (but pathotypes or races are not distinguished and thus these are not very useful), and 4 chemical descriptors. Wild materials have been identified and described, and new species published. Interesting resistances are known amongst wild species to the potato leaf roll virus, potato spindle tuber viroid, and different pathotypes or races of bacterial wilt, the two cyst nematodes, and viruses X and Y. Evaluation at IITA for resistance to the sweet potato virus disease complex and weevil has shown promise with 55 lines out of 414 tested in the glasshouse showing a high degree of resistance to Meloidogyne incognita and M.javanica. Much work at CIP and in many institutes in N. America, Europe and elsewhere involves the breaking of crossability barriers by means of conventional methods using bridging species and through the use of modern in vitro techniques such as protoplast fusion and embryo culture.

At CIP a strategy of potato population breeding and recurrent selection is used to increase the frequency of resistance genes in gene pools. However, in the first ten years of CIP's work, clones from developed country programs were mostly used to contribute good agronomic characters so as to make good materials quickly available for developing countries. The genetic resources collection is used as an essential source of resistance, especially to cyst nematodes, frost and viruses, and adaptation to the lowland tropics. Wild materials particularly are being used for resistance to Phytophthora,

bacterial wilt, root knot and cyst nematodes, potato spindle tuber viroid and leaf roll and X viruses. All potato evaluation results are deposited in a computerized data storage system and are available on demand but, unfortunately, no inventories have been published and no detailed information on wild species can be obtained. Results of breeding research on potato are described in chapter 6.

12.4.7 Cassava and yams

CIAT has accepted the global mandate for cassava germplasm; substantial collections are also kept at IITA. IITA has a global mandate for yam improvement. More wild species collections are still needed from the centers of diversity in S.W. Mexico and N.E. Brazil. Of an estimated total of 98 wild species, all but 19 are found in S. America. CIAT has 31 wild species but the number of samples of some may be small. They are of interest to breeders for possible presence of characters conveying low hydrocyanic acid content, disease and pest resistance, high starch and drought resistance. Materials have been collected by CIAT in collaboration with IBPGR and national programs in all the major distribution areas from Mexico to Paraguay.

The pace and influence of cultivated cassava exploration work is very good. There are three distinct strategies for cassava conservation at CIAT, the trial fields, seed collections and meristem collections. The total cassava holdings are 3,600 entries and over 2,000 of these have been successfully put into *in vitro* storage. A set of 40 to 50 elite lines is kept *in vitro* for distribution to institutes requesting them. Because of

quarantine restrictions, all intercontinental exchanges, and most international ones in Latin America can now only be made in the form of *in vitro* materials. Transfer of germplasm from 1973-1984 took place to 50 countries in the form of stakes (699), *in vitro* (832) and seeds (321,611).

Preliminary evaluations include yield, root quality and disease and insect resistance. Most lines are evaluated at four sites, (namely, N. coast, a mid-altitude zone, E. plains and the highlands). CIAT has not yet found resistance in the cultigen to the African mosaic virus but this is found in the wild species, *Manihot glaziovii*, and, in Africa, IITA has identified many resistant lines that are widely grown by farmers. There is an urgent need to extend the evaluation of the wild species. Promising levels of resistance have been found to thrips, mites, whiteflies, mealybugs and lacebugs. Tolerance to low soil fertility has also been found. Some work on bridge hybrids has been in progress to broaden the genetic base and to concentrate useful characters in advanced breeding lines. Little work has yet been attempted to introgress useful characters from wild *Manihot* species into the cultigen. Basic research on wild species and their genetic compatibility with the cultigen is still at an early stage although IITA has successfully made three inter-specific croses (matching its achievements with sweet potato).

IITA maintains a germplasm collection for white yam (*Dioscorea rotundate*), water yam (*D. alata*), yellow yam (*D. cayenensis*), and trifoliate yam (*D. dumetorum*). These include 741 accessions for *D. rotundata*, 310 for *D. alata* and smaller numbers for the other species.

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Following extensive studies of flowering habit, seed behavior, plant physiology and activity of pollinating agents under field conditions, IITA scientists have perfected the basic techniques of hybridization, seed germination, seedling establishment, and rapid multiplication of the selections for artificial yam breeding. Using these techniques, many promising white yam clones have been produced.

Many water yam clones that have resistance to necrosis disease and have high yield potential (up to 40 t/ha when staked and 20 t/ha unstaked) have been selected from the germplasm collection. Some of these have tubers that are round, uniform in shape and size and have thick periderms. They are therefore ideal for mechanical harvesting and processing. Such clones include TD 291, TDa 251, TDa 310, and TD5.

12.4.8 Faba beans and lentil

ICARDA has accepted the world mandate for these two crops. Collections of faba beans are still seriously under-represented from countries such as China, Iran and India. However, a proper survey based on the distribution of collecting sites is still needed. ICARDA has set out priorities for collecting in N. Africa. W. and S. Asia and Chile. Collections of wild lentils urgently need more material, and are very under-represented. A proper survey of passport data in the existing collections is required.

ICARDA holds major collections of faba beans (2791) and lentils (5838) and will hold more when its long-term (Italian financed) storage facilities are

available. Materials are shared with requesters. With encouragement from IBPGR, more of both crops and their wild relatives will be collected.

The method adopted for screening the land race samples of faba bean, when each sample is highly variable within itself, is to screen the pure lines extracted from each, whilst still retaining the original population sample. Good sources of Botrytis and Ascochyta resistance have been identified and selections able to grow in low rainfall areas have emerged. Nematode and Orobanche resistance has also been found in the genetic resources materials. Wild lentils have not yet been properly evaluated. In examining 4550 accessions, features useful to breeders were identified including cold tolerance, height, lodging resistance, and rust and Ascochyta resistance. Collaboration with Egypt and Sudan in screening for certain important pests and diseases has also been arranged. After crossing and selection the materials go to yield trials followed by international yield trials and screening nurseries. Other objectives, in addition to high yield, resistances and drought tolerance, are protein content and the elimination of favism factors. Several training courses in genetic resources work for Arab speaking participants have been organized at ICARDA and ACSAD with the help of the IBPGR regional coordinator for N. Africa and the Middle East. The book on genetic resources for chickpeas, faba beans and lentils published by ICARDA in collaboration with IBPGR should facilitate further work on these species.

12.4.9 Phaseolus beans

CIAT has accepted responsibility for the exploration, storage and characterization of all four cultivated Phaseolus species, together with their

wild relatives. The breeding and improvement program is confined to one species only, P. vulgaris. No far-reaching surveys have been made of materials in the various Phaseolus collections in different parts of the world with a view to looking for gaps in species and countries where collecting should be undertaken. It seems clear that more efforts are needed to collect P. coccineus, P. lunatus and P. acutifolius, even allowing for the fact that their areas of cultivation are not so extensive as that of P. vulgaris.

CIAT has made or encouraged expeditions, generally with IBPGR funding, to the Phaseolus regions of primary diversity and origin, particularly Mexico, Central America, Colombia, Venezuela, Ecuador, Peru, Bolivia, Argentina and Brazil. Collections have been made by national scientists and by USDA and IITA teams in Africa, Asia, the Iberian peninsula and elsewhere.

Storage conditions are of good quality. At present, 17,000 samples are in the active collection and 3000 in the base collection. There are quarantine problems concerned with the introduction of materials from Africa, Asia, E. Europe and Brazil. Six thousand samples of this type lie, losing viability, untouched in the active store, since the Colombian authorities require each sample to be grown for a season in a quarantine house and the national facilities for this are inadequate.

Transfer of raw germplasm to other countries has included nearly 25,000 samples, mainly in response to requests for specific characters from national program breeders, entomologists and pathologists. In addition, 74,900 samples were passed to the CIAT bean breeding program. Most of the screening at CIAT

has been done on the P. vulgaris materials in connection with the breeding program. The materials are characterized using 28 out of the 59 IBPGR morpho-agronomic characters. Some 12,000 accessions have been processed in this way and the information passed into computer storage. In all the plots, the accessions are evaluated for growth, adaptation and yield as well as field resistance to diseases and pests. This is followed by more careful evaluation for resistance to bean golden mosaic virus, common bacterial blight, Ascochyta leaf spot, leafhopper, Zabrotes and Acanthoscelides. Breeding results with these crops are described in chapter 6.

12.4.10 Chickpea and pigeonpea

The cultivated chickpea extends mainly through the Mediterranean basin, the Middle East, central Asia, India and Ethiopia, but is also grown in many other countries. The distribution of the wild species is also well known. Of the two types, "desi" and "kabuli", ICRISAT takes responsibility for desi, whilst joint responsibility for kabuli is shared by ICARDA and ICRISAT. The distribution, taxonomy and origin of pigeonpea (one of ICRISAT's mandate responsibilities) are well surveyed, although more wild collections are still needed.

ICRISAT holds over 13,000 chickpea entries from 40 countries, though certainly many of these will prove to be duplicates. ICARDA inherited 1798 kabuli chickpea accessions in 1977 from the Ford Foundation program and has added a further 2627 accessions of which most are said to be land races. Pigeonpea materials at ICRISAT number 10,000 samples from 36 countries,

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including 46 samples of related wild species. Considerable exploration is needed for wild species in the genera Cajanus and Atylosia.

ICRISAT's chickpea evaluation program is very extensive. All germplasm has been screened for Fusarium wilt and dry rot (Macrophomina). Some medium resistant lines to Ascochyta blight were found from screening work in N. India and by ICARDA In Syria. Screening from chickpea stunt (pea leafroll virus) has not been carried out systematically. Some work has been carried out also on nematodes, iron deficiency and soil moisture stress. Some promising lines of chickpea have shown increased capacity for nitrogen fixation.

Pigeonpea has also received much attention of ICRISAT from the evaluation viewpoint. Almost the entire collection has been screened for Fusarium wilt resistance, and 30 lines with good resistance were identified. Phytopthora stem and leaf blight has received attention, but with less promising results. The entire collection of chickpea and pigeonpea has been screened for Heliothis resistance and a few promising accessions have been identified. At ICARDA, 3300 kabuli chickpea accessions were evaluated for morpho-agronomic characters, as well as Ascochyta blight, cold tolerance, iron deficiencies and photoperiod insensitivity, and many useful lines were identified.

Nine wild annual and six perennial Cicer species were once assembled at ICRISAT. Annual species are being maintained satisfactorily but the perennial species are difficult to maintain. With pigeonpea, Atylosia latisepala was crossed successfully with the cultigen, Calanus cajan.

12.4.11 Groundnuts

This section deals mainly with the common groundnut, Arachis hypogaea, which is an ICRISAT mandate crop. The other two groundnuts, Vigna (Voandzeia) subterranea (Bambarra groundnut) and Kerstingiella geocarpa (Kersting's groundnut) are grown to a limited extent in Africa and have been collected by IITA, even though they are not mandate crops.

Arachis is native to South America, where all the related wild species in the genus are to be found. There have been many surveys of both cultivated and wild materials. Although the cultigen is fairly well explored there are many areas that need attention, whilst collection trips into the hinterland of Brazil and adjacent regions, as well as to Asian and African countries, are still needed.

ICRISAT stores 11,448 accessions of cultivated material from 84 countries; a good representation of the total genetic diversity. At IITA there are 1100 accessions of Bambarra groundnut, but only 47 accessions of Kersting's groundnut. Large collections of Bambarra groundnuts have been sent to Burkina Faso, Zambia and Japan for testing and breeding.

Evaluation work undertaken on groundnuts at ICRISAT has been developed to a high level. Groundnut descriptors were developed in 1981, in collaboration with IBPGR, and include passport, morpho-agronomic, disease, pest and stress descriptors. Some 9000 accessions have been characterized. Breeding research on groundnuts is discussed in chapter 6.

12.4.12 Vigna and Soya

IITA is responsible for the storage of a global base collection of cowpea (Vigna unguiculata), as well as for its collection and improvement. It also holds the mandate for the storage and improvement of soybean (Glycine max). Cowpea is indigenous to Africa with its center of diversity in W. Africa. High priority is accorded to the collection of wild cowpea relatives throughout Africa. Soybean was domesticated in N.E. China and there is little diversity in Africa. Most collections are held in China, Japan, U.S.A., Korea, AVRDC, Australia and India, with smaller numbers available in Indonesia, Nigeria and Brazil. IITA has 1350 accessions of soybeans.

IITA has also established connections with Asian countries for exploration in 1985-87. Achievements for cultivated cowpea exploration are excellent. IITA has 200 wild cowpea accessions. A long-term storage facility is now available at IITA. The cultivated cowpea collection now stands at 11,800 accessions, obtained from 85 different countries. From 1978-83, 10,651 samples of cowpea germplasm were distributed to over 50 different countries, half of these in Africa. The genetic resources unit has characterized about 9000 accessions for agrobotanical features, and, in collaboration with the crop improvement programs, has evaluated materials for disease, pest and stress resistance. Sources of resistance to bruchids, thrips, aphids, leafhopper, mosaic virus, and cowpea mosaic virus were found. Some useful drought resistance, earliness and better plant type characters were also identified. General screening for agronomic characters is also under way, and lines with good seed storability have been found in Indonesian germplasm.

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Good root-nodulating lines have also been identified. No soybean pre-breeding in the usual sense has yet taken place at IITA. Breeding research is described in chapter 6.

12.4.13 Forage grasses and legumes

The mandate for exploration and conservation of temperate to warm temperate forages from the drier regions of N. Africa and the Middle East has been accepted by ICARDA. CIAT has accepted responsibility for tropical forage germplasm, with special emphasis on Latin America. ILCA is responsible for graze and browse forages (chiefly legumes) from Africa and especially the Trifolium species from the African highlands. Some amount of overlap might be presupposed but cooperation and exchange of information between centers prevents any excessive duplication of effort. Most of ICARDA's efforts are directed towards Medicago and Trifolium. CIAT has made some attempts at surveys. There are 24 grass genera of interest, and of these, eight are considered to be of greatest importance (Andropogon, Hyparrhenia, Panicum, Setaria, Paspalum, Brachiaria, Hemarthria and Melinus: 25 legume genera are listed in the program, of which five are rated of highest importance (Stylosanthes, Zornia, Centrosema, Pueraria and Desmodium). ILCA commenced its forage program in 1980, so has not been able to progress too far. Detailed collection plans have been worked out, concentrating on the indigenous Trifolium species of the E. African highlands. ICARDA received 9476 samples in the 1979-81 period from 35 countries, including some from existing collections. In 1984, ICARDA collections were made in Syria, Cyprus and in Morocco.

CIAT has made extensive collections in Latin America since 1979, particularly of legumes. The collecting trips outside Colombia are generally made in collaboration with national institutes. The Latin American grasses are not so useful as those of Africa, and even Asia, so collections are received through exchange to some extent. The CIAT team is also collecting in Africa, some in collaboration with ILCA. Impacts from ILCA exploration work hold good promise. ICARDA's collection is 90 percent legumes and consists of some 16,800 samples. From 1979 to 1984, 3636 samples were distributed, mostly to developing countries. CIAT has no formal mandate to conserve forage germplasm but clearly should and does deposit materials in the gene bank. The collection amounts to more than 13,000 accessions, of which 11,900 are legumes. The whole collection is under short- to medium-term storage which is unsatisfactory. Distribution of samples in the period 1980-84 was good, with 7318 samples going to national programs. ILCA also lacks suitable storage facilities. Most of the ICARDA evaluation work is carried out at the headquarters field station at Tel Hadya. In collaboration with the crop sections, more than 1800 genotypes of vetches, peas and medics have been screened for disease resistance and for producing self-regenerating pastures. M. rigidula is most promising from this latter point of view. Disease resistance screening was done also at disease "hot spots" on the Syrian coast.

Evaluation at CIAT is moving ahead rapidly. The screening process is divided into five stages, lines which are successful in a lower one passing into the next higher. Stage I screening is carried out at CIAT and Quilichao for individual plants. Stage II takes place at Carimagua (Llanos) and Brasilia (Campo Cerrado). Stage III subjects promising lines to grazing.

Stage IV assesses yields, grazing preferences, nutritive value, etc. Stage V is the final stage, under commercial conditions. A range of nine promising "key" legume species was identified - three of Stylosanthes, three of Centrosema, Desmodium ovalifolium, Pueraria phaseoloides and Zornia sp. An active breeding program is under way at CIAT especially for anthracnose resistance in Stylosanthes guianensis. Selections of the African grass, Andropogon gayanus released by ICA in Colombia under the name "Carimagua I" and by EMBRAPA in Brazil as "Planaltina" show excellent adaptation to low-fertility acid soils with high aluminum content, as well as tolerance to pests and diseases, high drought and fire tolerance and high productivity.

The exploration and collection of tropical pasture species progresses far too slowly. CIAT's programs of evaluation, breeding and varietal releases have progressed much further than those of ICARDA and ILCA, which have had much less time available in which to accomplish them. The lack of good storage facilities is unfortunate.

12.5 Coda

* A center-centric focus on the steps anticedent to the production of advanced lines and varieties is taken in this chapter. The centers are relative latecomers to the field but now play vital roles in respect to many food crops.

* The scheme for considering plant germplasm work involves aspects of surveys, exploration, conservation, evaluation, enhancement, breeding, training, information retrieval and research.

* A major achievement of the IBPGR in its first decade has been to contribute to an increased awareness that genetic variation stored in cultivated crops and related wild species is an important natural resource. The effects of plant breeding are often antagonistic to the maintenance of genetic variation even though the latter is its basic resource. Genetic resources are primarily seen as a source of identifiable characters and only seldom as a source of increased overall genetic variation.

* IBPGR recognizes that its primary task is encouragement of genetic resources conservation, documentation, evaluation and utilization. It has encouraged development of networks of base collections and of national genebanks rather than building and operating genebanks. IBPGR is among the most international of the centers as it works with more than 100 countries. Priorities rest on (a) risk of genetic erosion, (b) economic and social importance, (c) plant breeders' requirements and (d) size and scope of existing collections.

* Genebanks now have substantial collections of most major crops as well as material from many other important crops. A large amount of the genetic diversity of the major crops has now been collected.

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* Base collections are those which have the capability of long-term storage. An active collection, in contrast, is used for regeneration, multiplication, exchange, evaluation and documentation. A base collection must be closely associated with an active collection since base collections do not usually become involved in germplasm exchange. This is not well understood, and misunderstandings have led to unwarranted charges of restrictions on free flow of germplasm.

* Wheat and wheat relatives are stored in gene banks in various parts of the world. Further collecting still needs to be done. The CIMMYT wheat collection is largely a breeders' working collection. The genetic base is rather narrow. The ICARDA position in respect to durum wheat is better. CIMMYT can also be criticized for the interpetation that it makes of its present mandate and thus for its lack of interest in surveys and exploration and for its reluctance to accept global responsibility for bread-wheat germplasm. While its record for the breeding and release of varieties in cooperation with national programs is spectacular, it may well be difficult to maintain this much longer if the genetic base of the CIMMYT collections is not considerably broadened.

* Further barley collections should be made in the ICARDA mandate area of N. Africa and the Middle East. A crash program of barley land race and wild species collections is needed before much genetic diversity is lost. Conventional barley breeding using European and American breeding lines and cultivars is not very useful in solving problems of drought and salt tolerance in the ICARDA mandate areas.

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* Rice exploration activities have been well coordinated and documented. From 1971-84 some 39,200 samples were collected in Asian countries, a little less than one third of which were obtained by IRRI expeditions. In Africa, coordinated efforts between IITA, ORSTOM, WARDA, etc. provided nearly 9000 samples. An excellent program for rice storage and regeneration is in operation at IRRI and there are now some 70,000 entries, including 1100 wild species accessions. The input of disease- and pest-resistant and stress-tolerant germplasm into rice gene pools is progressing actively with some significant successes. Material from the IITA collection has been used widely by IRRI, CIAT, WARDA and IRAT. At both IRRI and IITA, training in genetic resources work and related disciplines has been good.

* The CIMMYT maize bank, which contains most but not all the Latin American germplasm, has no computerized data storage and retrieval system from which inventories or computer-generated maps can be constructed. In November 1984 CIMMYT agreed to accept global responsibility for maize germplasm from 1985. A great range of land race material has been collected in the past and it is to be hoped that this still exists in a viable condition in the banks. CIMMYT breeders are developing broad-based gene pools into which promising germplasm is continually being inserted.

* Good collections of cultivated sorghums exist, although there is extremely poor representation of wild forms in the gene banks. Much more collecting is needed, especially in Ethiopia, eastern Sudan, Uganda, Burundi, Rwanda, Kenya and Tanzania. ICRISAT has evaluated more than 20,000 lines using

morpho-agronomic characters and some disease, pest and drought resistance has been recorded. Screening against grain mould, downy mildew, Striga and midge has been carried out. Large-scale pearl millet characterization and screening for resistance to downy mildew, ergot and smut has also been undertaken. Screening is carried out in W. Africa (Niger), Mexico (at CIMMYT), India and Zimbabwe.

* CIP has made a major impact in potato surveys. By 1980, over 90 percent of the total cultivated potato germplasm had been collected due to a crash program of CIP. Wild species have also been systematically collected, particularly in Ecuador, Peru and Bolivia.

* IITA has collected about 1000 clones of sweet potato since 1976 in expeditions to 18 African countries. AVRDC, with help from IBPGR, has established a very large collection. The cultivated potato collection at CIP consists of 5000 samples. In vitro storage has been developed, and currently 250 clones are being stored. CIP is undertaking research, often in collaboration with industrial countries, on cryopreservation, inheritance studies, virus detection, production of true seed varieties, and on genetic stability during in vitro storage and under cryopreservation. Between 1981 and 1984, IITA distributed nearly 8000 samples of sweet potato clones in tissue culture to 49 countries worldwide.

* CIAT has accepted the global mandate for cassava germplasm: substantial collections are also kept at IITA. More wild species collections are still needed from the centers of diversity in S.W. Mexico and N.E. Brazil.

Because of quarantine restrictions, all intercontinental exchanges, and most international ones in Latin America can now only be made in the form of in vitro materials. There is an urgent need to extend the evaluation of the wild species. Promising levels of resistance have been found to thrips, mites, whiteflies, mealybugs and lacebugs.

* ICARDA holds major collections of faba beans and lentils. Good sources of Botrytis, Ascochyta and drought resistance have been identified. CIAT has responsibility for the exploration, storage and characterization of all four cultivated Phaseolus species. The breeding and improvement program is confined to P. vulgaris. More efforts are needed to collect P. coccineus P. lunatus and P. acutifolius. At present, 17,000 samples are in the active collection and 3000 in the base collection. There are quarantine problems concerned with the introduction of materials and 6000 samples lie untouched in store losing viability.

* ICRISAT takes responsibility for desi chickpea whilst joint responsibility for kabuli chickpea is shared by ICARDA and ICRISAT. ICRISAT holds over 13,000 chickpea entries from 40 countries. Pigeonpea materials at ICRISAT number 10,000 samples from 36 countries, including 46 samples of related wild species. Considerable exploration is needed for wild species in the genera Calanus and Atylosia. The entire collection of chickpea and pigeonpea has been screened for Heliothis resistance (at ICRISAT) and the collection of chickpeas for Ascochyta blight resistance (at ICARDA) and promising accessions have been identified.

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* The common groundnut, Arachis hypogaea, is an ICRISAT mandate crop. Arachis is native to South America. ICRISAT stores 11,448 accessions of cultivated material from 84 countries. Breeding is carried out only at ICRISAT center and Malawi. Aspergillus flavus resistant lines are bred with high-yielding characteristics.

* Cowpea is indigenous to Africa with its center of diversity in W. Africa. IITA exploration for cultivated cowpea is excellent but not very impressive for wild cowpeas or soybean. More than 10,000 samples of cowpea germplasm have been distributed to over 50 different countries, half of these in Africa. Useful disease and drought resistance, earliness and better plant type characters have been identified.

* For forages, most of ICARDA's efforts are directed towards Medicago and Trifolium and CIAT to many tropical grasses and legumes including Stylosanthes, Zornia, Centrosema, Pueraria and Desmodium. ILCA concentrates on Trifolium species of E. Africa. CIAT has made extensive collections in Latin America. An active breeding program is under way at CIAT for anthracnose resistance in Stylosanthes guianensis. However, the exploration and collection of tropical pasture species progresses far too slowly.

* An important aspect of IBPGR's work has been to promote minimal descriptor lists for "passport" (accession and collection) data.

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* IBPGR has directly or indirectly organized 500 missions in 88 countries, particularly in the tropics and sub-tropics resulting in over 100,000 samples in gene banks.

* Although effort and support have been provided for microcomputers, a steady flow of data into the systems and out again to meet requests is still not attained in most countries.

* National genetic resources programs have been established in 83 countries, of which 50 were assisted or stimulated by IBPGR. Some regions are more advanced than others. Latin America, W. Africa and E. Africa are just in the initial stages.

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13 CROP PROTECTION

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13 CROP PROTECTION

13.1 Introduction

The centers have received both praise and criticism for their efforts in crop improvement. The nature of their mission and the complexity of the constraints with which they deal, render an evaluation of their crop protection impact difficult. This chapter summarizes a review, assessment, and appraisal of the impacts of the centers on national research programs and on farm-level crop protection by Teng and MacKenzie (1985). Research center, commodities, national programs, and national farm-level production statistics were examined as a basis for these judgments.

13.2 Center Activities and Possibilities

13.2.1 Overview of present activities

As noted in chapter 2, the mandates for the centers range from broad regional to global responsibility, for one to a few crops. There is no consistent formulation of goals or objectives vis-a-vis plant protection, and perhaps none is required. The consequences of such broad mandates, the influence of the TAC in determining priorities, and the reality of limited budgetary resources must all be considered when assessing the impact of the centers.

Budgetary constraints are only part of the reality of crop protection on a global scale. The many pests and pathogens that attack food crops in the developing world require complex decisions on priorities that depend on regional and sometimes local environmental interactions, farming systems, and economic forces, together with inevitably limited knowledge. Steering a safe course of research through these considerations is a complex and at times, impossible task.

The centers have made resistance breeding the keystone of their approach to plant protection. This has proven to be a good choice. It has permitted the distribution of modern varieties as a "technology package" and thereby has circumnavigated the difficulties of knowledge distribution that are so frustrating in many developing countries.

The earlier decision to focus on breeding for pest resistance is an appropriate topic for current review. In the past decade, there have been significant developments in several disciplines of agriculture that can contribute to crop protection. A review of those topics is included in the following section.

13.2.2 Components of contemporary crop protection

Members of the pest-control-related disciplines of entomology, plant pathology, nematology and weed science, and the agronomists who study stress factors, have now come to recognize that, for many crop protection problems,

no single solution is appropriate. There is an increasing emphasis on the need to "mix and match" crop protection strategies better to address the problems of pest variability, interactions with the environment, economics, pesticide safety and many other factors. Integrated crop protection goes far beyond integrated pest management (IPM). It offers a broader view of the production system and incorporates normal research tools, high technology and other components into an area of activity that is truly interdisciplinary. A review of the components of contemporary crop protection includes the following topics:

Resistance Breeding: the focal point of many crop improvement strategies has been breeding for resistance to pests. In many cases, very successful control of pest problems has been realized. In other cases, probably a minority, resistance breeding has failed because of the variation in the pest population. This "boom and bust" cycle of breeding has led many to conclude that there must be a better way to protect crops from pests.

Durable Resistance Breeding: Some have postulated the theoretical existence of durable resistance to pests. Many books have been written on durable resistance and considerable amounts of research have been devoted to its definition and intended utilization. The fact remains that, at present, no solid demonstration of durable resistance exists that is universally acceptable to the scientific community and there is continuing controversy as to what it really is.

Biological Control: Most research effort in biological control has focused on insect pests. Limited amounts of research in N. America, Europe and Australia have developed biological controls for commercial use.

Chemical Control: Best exemplified by the herbicides, fungicides, nematicides, and insecticides developed by international corporations, chemical control in agriculture is well established on a commercial scale. The centers have largely avoided research in chemical control except where they have had a direct impact on varietal release (e.g., herbicide sensitivity of improved cultivars).

Cultural Control: The manipulation of cultural procedures to take advantage of pest populations, or plant protection has received some research effort in the past few decades. Much of this effort is a renewed interest in practices such as crop rotation, "green mulches" for fungal or weed control, and water management for soilborne plant pathogens.

Integrated Control: Recent research has demonstrated complementarity between control procedures that have beneficial effects. For instance, it has been demonstrated that complementarity exists between some forms of resistance, which allows a reduced amount of fungicide for the control of potato late blight. Discoveries in this area offer the potential of reducing pesticide dependency.

Integrated Pest Management: Sponsored mostly be entomologists, researchers in IPM explore ways of combining strategies to reduce pesticide dependency. It encourages a more comprehensive view of the pest system in a crop population.

Pest Surveillance: Surveys for and monitoring of pests of crops are activities considered to be part of surveillance. Many well-developed programs, such as the USDA's North American Wheat Rust program, give much significant information useful to crop protection. Some aspects of the centers' international testing programs qualify as pest surveillance systems.

Pest Forecasting: The anticipation of past outbreaks through weather monitoring, pest surveillance, or by other information are categorized as pest forecasting. Far less of this research activity has taken place in the tropics than for temperate area crop pests.

Modelling: The synthesis of information through computer modelling has been a helpful research tool in developing crop protection strategies based on pest forecasting. The integration of crop growth models, environmental factors, and their interaction with pest development have opened new areas in the development of crop protection strategies.

Economic Thresholds: Decision analyses require valid interpretation of the consequences of pest build-up and the economic consequences of pest damage

to the crop. Economic thresholds are being developed for a number of important crop pests. The tropical region lags behind other regions in these discoveries. Entomology knowledge far outdistances that of the other disciplines concerned with pests of crops.

Population Dynamics: A thorough understanding of the population dynamics of insects and the epidemiology of plant diseases is crucial to designing crop protection systems. Significant advances have been made in some areas of population dynamics/epidemiology in the past 15 years. Much of this discovery awaits application.

Crop Loss Assessment: Economic thresholds focus on yield loss at the field level. Crop loss assessment looks at the impact of stresses on regional crop production. Originally it was thought that the aggregation of yield loss information could be used for crop loss assessments. More recent thinking separates yield loss assessment from crop loss assessment, and emphasizes the importance of crop losses in estimation of regional crop production.

Biotechnology: The new "tool" of agriculture offers an opportunity of genetically engineering crops that are better protected from pest attack. How this new technology will interface with crop protection remains to be described.

One distinguishing aspect of contemporary crop protection is that it begins with a holistic view of the cropping system. It attempts to comprehend

the pest biology, to be able to draw more proper conclusions and more realistic expectations for various pest control strategies. It does not, necessarily, use genetic resistance as the first line of defense.

13.3 The Centers' Contributions in Plant Protection

13.3.1 Sources of information

In order to make judgements on the impact of the centers on crop protection, many sources have been reviewed, representing much documentation which included center annual reports and external or quinquennial reviews, Consortium for International Crop Protection (CICP) trip reports (Berkeley, California), World Bank reports, interviews with staff members of centers, contacts with scientists who have visited or worked at centers, work experience of center consultants, and extensive literature searches.

13.3.2 Past impacts of the centers

The major impacts of the centers on food production to date have largely been in relatively highly controlled farming systems with semi-dwarf wheat and rice. Their successes represented germplasm improvement that could take advantage of improved cultural conditions. The semi-dwarf wheats were designed from the start to carry resistance to stripe rust, stem rust and leaf rust, the major diseases of wheat. The strategy of exposing successive generations to pathogens at different locations, permitted the breeders to develop varieties with substantial levels of resistance. With photoperiod

insensitivity and the rather homogeneous ecology over which wheat is grown in developing countries from Mexico to N. Africa and the Middle East, and to India and Pakistan, the varieties were quite successful. With the success of the modern wheats outside Mexico, scientific and government interest permitted the use of sites in India, Kenya and elsewhere for screening to broaden further the range of resistance. Most of the semi-dwarfs grown, even today, carry resistance from those early lines.

IRRI's first semi-dwarf rice, IR8, while very high yielding, was notorious for its susceptability to a wide range of insect and disease pests. However, IRRI staff members recognized this and were conducting an intensive resistance breeding program for tungro virus, its vector the green leaf hopper, bacterial blight and others even as IR8 was pressed into service by the Philippine government (Chandler 1982). The second IRRI variety, IR20, was ready with resistance when a tungro virus outbreak swept the Philippines, and forced most farmers to abandon IR8.

Subsequent pest attacks at the IRRI experiment station made it possible for researchers to develop resistance to a range of other pests. They were not able to deal with pests not native to the Philippines, such as gall midge, but Indian researchers did address that problem as well as different sub-species and biotypes of major pests that did not exist in the Philippines. In general, these efforts have been directed at incorporating major gene resistance, as contrasted to what is now called "durable

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resistance" although the resistance to most rice pests has been rather durable, the major exception being to the brown planthopper.

Center plant breeders working on other crops have followed similar strategies of resistance breeding, and this approach has been quite successful for incorporating genetic resistance into materials suitable for farmers (see Table 13.1 below). Since the area planted to center-related varieties of the other crops is much less than the area of wheat and rice, their impact has been correspondingly smaller.

Even for wheat and rice, the global mandates of the centers realistically imply that not all factors that stress wheat and rice could be dealt with in the breeding programs. Some pest problems, such as rice blast, are far less severe under some cultural conditions. High-input flooded semi-dwarf rices are characteristically resistant to blast disease as a consequence of flooding. Similar varieties grown "upland" are highly susceptible to blast and would be commercially unacceptable. Conversely, the higher use of nitrogen fertilizer has contributed to aggravating other pest problems. On balance, a realistic assessment of the semi-dwarf wheat and rice varieties and their widespread adoption implies a positive contribution of that effort to crop protection.

The strategy of germplasm improvement worked well for wheat and rice. It may, however, be less appropriate for several other crops now being researched

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Table 13.1 Farm Level Impact of Center Plant Protection Research

Strategy	Rice	Wheat	Maize	Sorg hum	Prl Mlt	Pota to	Cass ava	Sw pot	Cow pea	Chk pea
Resistance breeding	****	****	***	***	***	*	**	**	*	**
Biological control						*	***			
Chemical control	***			*	*	*	*			*
Cultural control							*			
Integrated control	*	*				*				
Integrated pest management	**	*								
Pest surveillance	**	**								
Pest surveys	**	*								
Pest monitoring	**	*								
Pest forecasting										
Modelling										
Economic thresholds	**									
Population dynamics	*									
Crop loss assessment										
Biotechnology						*				

(****) = Major visible impact at farm level

( ) = No vlsible impact at farm level.

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at the centers. It has been suggested by a number of observers that an approach to research based on seeking widely-adaptable photoperiod-insensitive, high-input-responsive varieties may not work well with crops such as cassava, maize, chickpea, cowpea, pearl millet, or sorghum. If this is so, and if the argument can be sustained that the success of the semi-dwarf wheats and rices was in distributing such technology through the "improved seed", a new strategy perhaps must be developed that is appropriate for these other crops. In fact, different strategies may be needed for different crops. Notwithstanding this question of optimal strategy, the systematic and focused work of CIMMYT and IRRI did, however, provide an operational example of applied research that could be used for initiating similar work in the other centers and in national research programs.

Another impact of the centers has been the transmission of high-quality knowledge in many aspects of crop production, including crop protection. This knowledge has been manifested as publications, seminars, and as trainees, graduate students, and post doctorates who have gone on to address the task of increasing food production.

The semi-dwarf varieties have been accused of creating a "boom and bust" cycle but this accusation seems unfair. There are no reliable data to show that they have contributed to pest-induced yield losses that are now either more prevalent or more severe than before their introduction. Some have raised questions about the rice tungro (in the Philippines 1971-72) and blast

(in S. Korea 1978-79) epidemics that seem to be associated with improved rice varieties. These were discrete events that were successfully countered with available alternatives. Evidence from the 1940s and 1950s shows that the same pests then had similar substantial effects, i.e., before the advent of the semi-dwarfs. These events are features of changing agriculture and not a direct consequence of improved cultivars although they are surely aggravated by increased cropping intensity (especially of the same crop) and by increased areas of more uniform varieties.

Another consequence of intensifying agriculture is the increased use of pesticides which has, however, contributed to the increased yields. Critics of new technology argue that the increased use of pesticides is counterproductive and should have been avoided. However, in order to produce the needed food in land-scarce regions the sector must depend on increased yield, and pesticides play a role in attaining that objective.

Other significant contributions of the centers have been the establishment of global nurseries for the testing of germplasm under a variety of conditions. These nurseries have no counterpart in the developing world and contribute significantly to cultivar deployment.

Other impacts of the centers on crop protection have been through research studies on population dynamics and epidemiology, conducted as individual research scientists have seen a need. The scientific impact of this ad hoc

activity, where it exists, has been great. It extends internationally through publications, trainees and other scholars. It has been effective in modification of research programs, especially in redirecting plant breeding programs, and by broadening the scientific basis for understanding pest problems.

The centers have addressed the problems of crop pests by using plant breeding as a first line of defense. There is, presently, a recognition that crop protection is inseparable from farm production systems, and a broader view of the research needs is evident. However, apart from pest resistance, the contributions the centers' research on other plant protection methods to global crop yield increase is limited. Table 13.1 summarizes the contributions of centers' research to farmers' plant protection strategies.

13.3.3 Criticism of the centers' contributions

A number of scientific criticisms have been made of the research being conducted by the centers in crop protection. These are summarized below. To a large extent these reflect "sins of omission", indicating areas of research that could fruitfully be pursued, but which would require additional resources, rather than reducing resources devoted to resistance breeding.

The centers have been criticized for providing too little effort in cultural and biological control, crop loss assessment, surveillance methods and modelling, and in addressing the problems caused by rats and birds. It

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has been argued that the centers are logically the most appropriate institutions to undertake the research required to make alternative crop protection methods practical, and that they have failed in this obligation.

The centers have been criticized for conducting too little research that would develop marginal increases in crop production - including control measures for minor pests, and control measures for pests on minor crops. Critics have also raised questions about what the centers have done, charging them with various sins of omission in the plant protection area. For example, the centers have been criticized for developing improved cultivars which are input-responsive, leading to a general increase in the use of chemicals, especially herbicides, for plant protection. It is noted that the rate of increased pesticide use is higher in the developing than in industrial countries. However, other critics have charged the centers with avoiding research on chemical control of crop pests.

The centers have been criticized for having unrealistic expectations for crops other than rice and wheat that are now being researched. It is difficult to believe that genetic resistance will be an effective strategy for crop protection from pests that are known to be very destructive.

On the scientific side, the centers have been criticized for providing "homogenized" science to the developing countries. It has been opined that their training programs, graduate education, publications, and approaches to

problem solving have been made uniform at the expense of discovery and progress. They have also been criticized for developing little theory and few novel techniques or methods that could be used in national programs.

The centers have been criticized for failing to develop methods of distributing knowledge that are appropriate to reaching farmers in the developing world. Pointing to the USDA's Cooperative Extension Network critics ask, "Why haven't the centers developed a similar network?" In the same vein, some charge them with a lack of "knowledge synthesis" that would lead to practical applications of discoveries in the area of crop protection. These critics claim that the centers have had little discernible impact in crop protection at the farm level. Others have argued that it is the responsibility of the centers to develop technology, and that the development of systems for teaching such results to farmers is covered by the FAO working in collaboration with national extension services.

13.3.4 Opportunities for increased activity

Not all of the above criticisms can be taken seriously. Some, however, should be seriously considered by staff of the centers. The centers are fortunate in that the integration of disciplines on research projects can address broader issues in a way that may be difficult, say, for academic departments. By limiting the number of crops researched at a center and by focusing on problems using several disciplines, it was envisioned that certain types of research would be more efficiently accomplished. Such

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interdisciplinary effort comes at a price. The leadership of plant breeding in many such interdisciplinary teams often results in a strong emphasis on breeding for resistance at the expense of other pest protection strategies. A careful review of interdisciplinary research to ensure that all appropriate aspects of crop protection have a possibility of being researched is advisable.

The nature of the research and the historical emphasis on breeding for resistance provides an opportunity for more basic research in the genetics of resistance. This information and attendant theory will be valuable for national plant breeding programs which do not have the resources, staff or time to invest in this important area of research. One major topic that should be emphasized would be the genetics of durable resistance. There is a need to define, to identify, and to develop methods to utilize this form of resistance. The centers are appropriate locations to conduct such research. Waiting for industrial-country universities to unravel the interactions of genotype, environment and pest may take decades. By utilizing their global networks of test nurseries, the expansive germplasm banks, and their existing data bases, the centers are in the enviable position of being able to provide the leadership on research in durable resistance.

Although research on plant epidemiology and population dynamics of pests has made significant advances in temperate environments, tropical epidemiology is lagging far behind. Fundamental differences exist between the conditions

contributing to epidemics separated by crop cycles versus those in a continuous cycle.

More research is needed in the evaluation of pesticides and on pesticide safety. This would be an appropriate activity for the centers as a complement to national programs and as an investment that would indirectly have an impact at the farm level. Leaving this important research almost totally to pesticide corporations or national programs does not seem wise.

It seems also that more research is needed to understand the contributions of pest stress to production. This information would be useful for research planning as well as for crop production forecasting. The utilization of international nursery testing programs would provide the information-gathering network necessary to begin this important research activity. It must be done in such a way that national participants understand the value of data being collected and can see how they might reap some long-run benefits.

It is generally believed that, by increasing the resistance of cultivars, a decrease in the use of pesticides might be expected. Although this relationship seems reasonable and the objective noble, some authorities speculate that yield increases in the future from this strategy will tend to be marginal. Breeding for pest resistance will be more like the "running to keep in place typical of maintenance research," rather than giving large yield gains. Increased dependence on pesticides may be an inevitable

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consequence of tomorrow's food production system in developing countries just as it is in industrial countries today. Research should begin now to recognize that likelihood - even though there are moves in many parts of the industrial world to endeavor to limit use of pesticides and their adverse environmental effects.

Perhaps more palatable than chemical pesticides might be research into the area of naturally derived pesticides, which may be more ecologically acceptable and of less risk to the health of the individual applicator and the consumer. These should not be ignored.

Finally, recognizing the constraints placed on the centers for funds, time and facilities, it is clear that new initiatives should be made to take advantage of research in industrial country universities that is appropriate to the needs of the centers' missions. Current resources in the universities are insufficient. Greater resources seemingly should be made available to tap the strengths of more universities to work with researchers in the centers for the benefit of the developing world.

13.4 Coda

* There is no consistent formulation of goals or objectives vis-a-vis plant protection work in the centers.

* The centers have made resistance breeding the keystone of their approach to plant protection.

* The semi-dwarf wheats were designed from the start to carry resistance to stripe rust, stem rust and leaf rust, the major diseases of wheat.

* IRRI's first semi-dwarf rice was notorious for its susceptibility to a wide range of insect and disease pests. Fortunately, a second variety was ready with resistance when needed. Subsequent efforts have been directed mainly at incorporating major gene resistance, as contrasted to what is now called "durable resistance".

* Center plant breeders working on other crops have followed similar strategies of resistance breeding, and this approach has been quite successful for incorporating genetic resistance into materials suitable for farmers. The strategy of germplasm improvement may, however, be less appropriate for several crops now being researched at the centers. Different strategies may be needed for different crops.

* Another impact of the centers has been the transmission of high-quality knowledge in many aspects of crop production--including crop protection.

* Other significant contributions of the centers have been the establishment of global nurseries for the testing of germplasm under a variety of conditions.

* The centers have been criticized for developing improved cultivars that are responsive to inputs, leading to a general increase in the use of chemicals, especially herbicides, for plant protection. The rate of increased pesticide use is higher in the developing than in the industrial countries. However, other critics have charged the centers with avoiding research on chemical control of crop pests.

* The centers are in the enviable poisition of being able to provide the leadership on research in durable resistance.

* More research is needed in the evaluation of pesticides and on pesticide safety. This would be an appropriate activity for the centers as a complement to national programs.

* Increased dependence on pesticides may be an inevitable consequence of tomorrow's food production system in developing countries just as it is in industrial countries today.

* New initiatives should be made to take advantage of university research in industrial countries that is appropriate to the centers' mission.

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14 TROPICAL LAND USE

14.1 Introduction

14.1.1 Objectives

Over the past decade, voices of protest against presumably unnecessary damage to the world's renewable resource endowment in humid tropical regions have become progressively more strident. These voices have emanated largely from the scientific community and from environmental lobbies. The concern for deteriorating quality of the humid tropics extends to the potential role of the centers in the process.

Focus has been primarily on the consequences of what may appear to be indiscriminate removal of tropical rainforest for development of agriculture and plantation forestry. Concern is expressed about: destruction of potentially valuable biomass that could be used for production of lumber, energy, food and chemicals: loss of habitat for flora and fauna, thus limiting genetic diversity that may have economic value to future generations: irreversible damage to on-site productivity of fragile soils; and accelerated erosion and runoff with negative downstream effects in terms of sedimentation, increased risks of flooding, and reduced productivity of fisheries and coastal ecosystems.

The purpose of this chapter is (a) to examine the nature and extent of change in the state of land, forest and water resources in humid tropical

areas which are traceable to intensified agricultural production and expansion of the agricultural frontier: and (b) to assess whether these changes may be partially attributable to the CGIAR system; in particular whether the centers' activities have exacerbated or ameliorated deterioration of the humid tropical environment.

14.1.2 Basic premises

The framework within which this assessment is made rests on three basic premises. First, much development involving forest clearing and use of land resources in humid tropical zones does not constitute sound resource management when measured by such criteria as internal rate of return, income distribution, employment generation or sustainability of the natural system's capacity to provide material and amenity inputs for current and future generations.

Second, the focus of this enquiry is on the apparent (or real) prejudicial consequences of large-scale removal of the forest cover for agricultural purposes, resulting from: the destruction of valuable forest resources, possible irreversible loss of genetic materials, destruction of soil resources through laterization, water and wind erosion, and downstream effects of changed flow regimes and siltation. The concern here is not with chemical pollution of the environment where center packages may either contribute to contamination, e.g., by promoting use of fertilizers, pesticides and herbicides, or reduce it by breeding plants for disease resistance or by developing techniques for biological control of diseases and weeds. The

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absorbtive capacity of the humid tropical environment is taken to be of such magnitude that pollution will be an insignificant issue, except in a few localized situations.

Third, the long-run capacity of renewable natural resources to supply humankind with material inputs and amenity services is equally deserving of the international community's concern as is the short-run increase in food supply. Recognition of multiple objectives implies conflict and tradeoffs which fall in the area of resource management. Assessment of conflict in this case hinges on a value judgement of how much degradation is "acceptable" given short-run food requirements for survival, coupled with the expectation that technological advance will eventually evolve economically viable means : (a) to reverse what is currently considered an irreversible loss of resource productivity: (b) to increase production from resources that are not irreversibly degraded: and, (c) to reduce the demand for primary products by reduction of post-harvest loss, more efficient marketing and slower population growth.

14.1.3 Approach

The following set of hypotheses will be examined. Degradation of the humid tropical environment (in terms of the sustainability of its capacity to supply inputs for subsistence and development) has been going on for thousands of years. However, until the mid 1900s, this process was slow and was relatively sustainable with slash-and-burn agriculture. In recent years, with rising expectations in the rural sector, increased population pressure, wider use of defoliants, herbicides and fertilizers, and mechanized forest clearing and road-building, the rate of deterioration of the tropical environment has accelerated alarmingly.

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On balance, the quality of the humid tropical environment seems to be better with than without CGIAR activities. On the positive side: (a) increased yields and nutritional value of food crops grown on existing arable land have reduced the pressure on fragile areas; (b) increased food supply has, in part, fostered rural to urban migration rather than rural-rural movement to tropical frontier lands; and (c) high-yielding low-cost varieties and new management techniques have the potential to stabilize slash-and-burn agriculture and to reduce the total area needed for the bush-fallow rotation:

On the negative side: (a) modern varieties have encouraged profitable cultivation of marginal lands, resulting in long-run irreversible damage to soils with prejudicial long-run downstream effects: (b) energy-, management-, and capital-intensive technologies used by producers with inadequate capital resources or management for their short-term gains in inappropriate zones, have contributed to long-term degradation of the ecosystem: and (c) focusing research to maximize the absolute increase in yields has led the centers to concentrate on the most productive ecosystems. This has increased relative poverty in marginal areas and left users of degrading or degradable lands without "appropriate" technologies.

With respect to the prejudicial hypotheses, the position of the centers responsible for research in crops and management practices for the humid tropics may be summarized as follows: (a) the varieties and management procedures developed are environmentally neutral, i.e., the use of modern varieties and associated production techniques will make no difference to the

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rate of degradation that would be expected under traditional practices: (b) the centers can hardly be held responsible for misuse of their research results by government or private agencies which influence the pattern of resource use in the humid tropics; and (c) with respect to developing technologies which, if misused in inappropriate zones, cause damage, the centers are "trapped": if they don't develop the technologies they can be accused of indifference to an inevitable process of agricultural expansion onto progressively more fragile areas; if they do develop the technologies, they are equally vulnerable to criticism if the technologies are wrongly applied.

14.2 The Nature and Extent of Environmental Damage in the Humid Tropics

Reduced environmental quality in the humid tropics attributable to agriculture stems primarily from the consequences of forest clearing. Other impacts include contamination of water with residues of production or processing, and the consequences for human health of irrigation schemes, or spread of disease through migration and agricultural settlement.

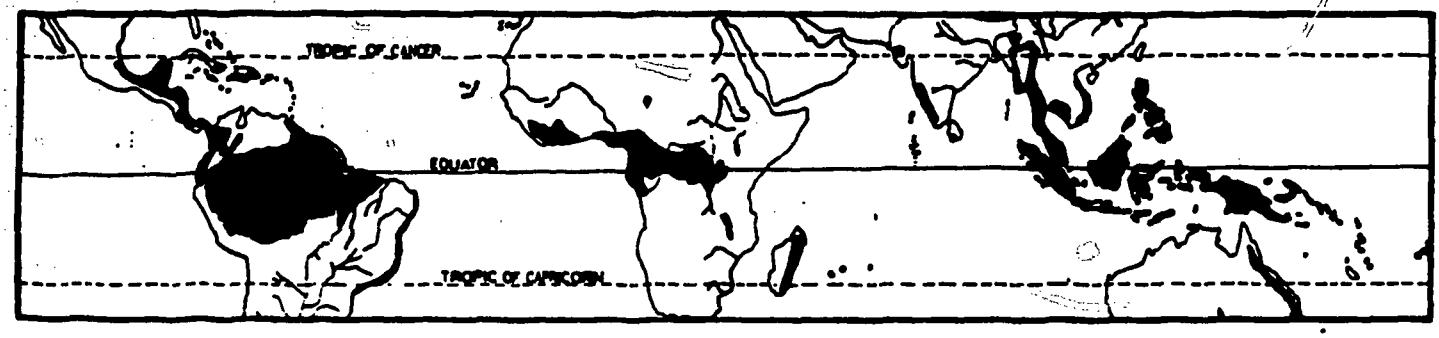
14.2.1 Overview of land clearing

The tropics comprise approximately 5 billion ha in 90 countries, of which around 1.2 billion ha are considered suitable for agriculture and livestock. About 2.3 billion ha are classified as humid forest "life-zones". Under a more restricted definition, the area formally covered by tropical rainforest is estimated to be in the range of 1 to 1.2 billion ha, of which 55 percent was in Latin America, 20 percent in Africa, 25 percent in S. and S.E. Asia

(see Figure 14.1). Total area of this forest cleared by 1980 was about 440 million ha, of which 150 million ha were in some form of permanent agriculture, 210 million ha were in a shifting agriculture-bush-fallow rotation and 80 million ha had degraded to unproductive vegetation such as Imperata cylindrica. In Malaysia, 75 percent of the land area was in forest in 1955, falling to 50 percent in 1980, i.e., clearing of 8.3 million ha. The forest area in Thailand was reduced by 11.7 million ha between 1960 and 1982, at an average rate of 0.43 million ha a year in the 1960s and 0.72 million ha a year in the 1970s. It is estimated that in Indonesia, on average, 1 million ha a year will have to be cleared for agriculture over the period 1981-2000. In all of S.E. Asia, it is estimated that annually: shifting cultivators encroach on 1.0-1.4 million ha of undisturbed or logged-over forest lands and clear 3-4 million ha from bush-fallow: timber and fuelwood are harvested from 2-3 million ha: 1 million ha of forest or bush-fallow are converted to permanent agriculture; and 0.4 million ha formally in agricultural production reverts to impoverished grasslands. The result of this process over the past 150 years is a reduction in tropical forest area from 400 million ha to 290 million ha. The annual rate of deforestation in Nigeria is placed at 0.5 million ha. In the Amazon region, it is estimated that, by 1982, 20 percent of the forest area, i.e. 110 million ha, had been cut, with the rate reaching 1.8 million ha a year in recent years (Alvim 1982). FAO (1979) estimated a rate of clearing of 5.6 million ha a year for 23 tropical countries in Latin America of which about 0.16 million ha (3 percent) were replanted.

It is difficult to make a clear distinction between forests cleared in the bush-fallow rotation and new lands brought in from primary or secondary

Figure 14.1
Tropical rain forest areas



forests (logged or unlogged) that lie outside the Swidden agricultural system. Couper et al., (1981) place annual clearing by shifting cultivators in all tropical regions at 10 million ha. Deforestation for new agricultural enterprises, whether shifting or permanent, is estimated by Palm et al., (1982) to range from 6-20 million ha annually. Oram et al., (1979) projected that, in order to meet food requirements in 36 low income countries of Sub-Saharan Africa and S. and S.E. Asia, public expenditure in the range of $800m annually will be required to expand agriculture on existing forest lands. Of this amount, $700m would be required for organized settlement of 1 million ha and $100m for infrastructure to support spontaneous colonization on 2.5 million ha annually. With inclusion of other countries in Africa and Asia plus the Latin American region, which alone accounts for 50-60 percent of the world's humid tropical lands, a global estimate of public expenditure might be in the order of $2-3 billion annually to support clearing of 6-10 million ha forest lands and its subsequent development for agriculture. Aside from possible damage through forest removal, there is also concern about the production effects and potential downstream damage from accelerating deterioration of 150 million ha of tropical watersheds now under some form of cropping or livestock exploitation (World Resources Institute 1984).

14.2.2 Consequences of land clearing

Damage arising from removal of the forest cover is conditioned, in large part, by subsequent use of the area cleared. If the land is rapidly returned to high-density permanent cover, the off-site damage may be low. The on-site damage constitutes a short-run loss of potentially valuable biomass and may

lead to a long-run loss of species diversity. There are about 150,000 kinds of plants in the humid tropics, some of which may, in the future, offer more efficient means of supplying energy, food and raw materials. Forest destruction may also have potential long-run climatic consequences due to increased concentrations of carbon dioxide in the atmosphere.

The primary damage, in terms of the productivity and sustainability of an ecosystem, is the destruction of soil fertility and erosion which occurs if land is not returned rapidly to a high-density cover crop. The question is not how to stop all forest clearing, thereby stopping all damage: rather, it is how are decisions made on areas and techniques used for removing the forest and subsequently using the land for agriculture which incur more or less damage on more or less fragile ecosystems, in the process of economic development?

Research at IITA provides a graphic illustration of on-site damage under various management options (Lal 1981). Four land-clearing methods (traditional manual, intensive manual, shear-blade and tree-pusher), three post-clearing tillage systems (traditional seeding, conventional tillage and no tillage) on four slopes were examined. Over a four-year period, soil loss on 1 percent slopes varied from 0.4 t/ha for the least-damaging option to 30 t/ha for the most damaging (Figure 14.2). On 15 percent slopes, the variation was from 60 to 520 t/ha. Maize yield and cumulative soil loss are very strongly negatively correlated.

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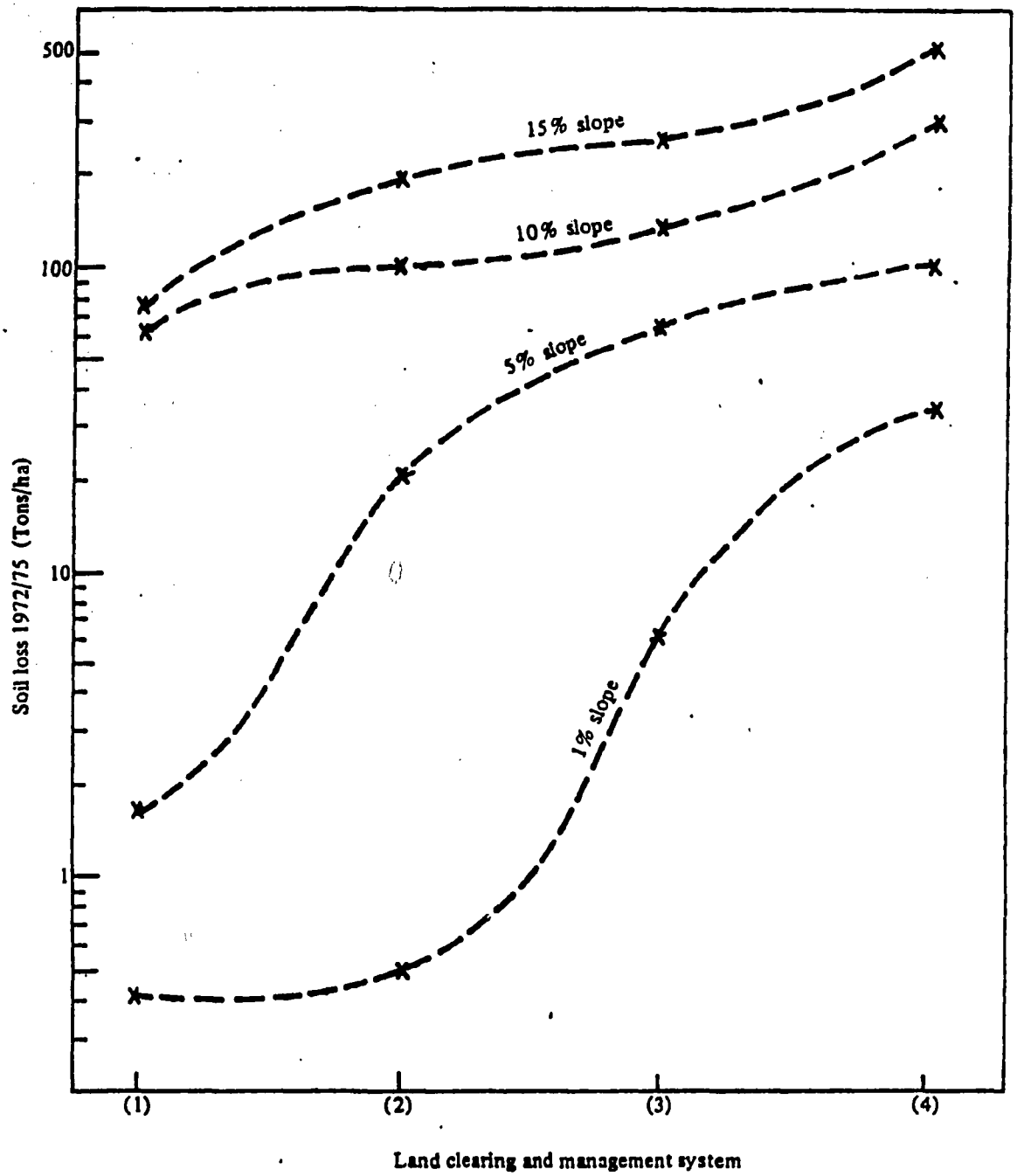
Figure 14.2

SOIL LOSS ACCORDING TO LAND MANAGEMENT SYSTEM AND SLOPE



Source: Lal, (1981), p. 371

The off-site effects are a function of the current or potential state of development downstream - infrastructure (irrigation, hydroelectricity, urban-industrial, etc.) and use of natural resources (agriculture, fisheries, etc.). One of the major effects of sedimentation is reduced useful life of reservoirs and higher cost of operating hydroelectric, irrigation, drainage, flood control and fluvial navigation schemes. Invariably, design standards have underestimated the dynamics of agricultural development and forest removal in the catchment areas. For instance, the design erosion rate for the Karangkates Dam in Indonesia was 0.25 mm/yr, based on data collected over the period 1950/60, giving a reservoir life of 100 years. Within 20 years population density was up 50 percent and erosion rate had increased 12 times (Soenaro 1984).

The (1980 actual and) potential hydroelectric capacity in the humid tropics was estimated to be of the order of 20,000 MW and 600,000 MW, respectively (Dunkerley et al., 1981). Sedimentation poses a threat to the hydroelectric potential, and the scale of existing and projected generation is such that it is of significant concern to policy makers in tropical countries. Although accelerated sedimentation also results from highways and mining, the major source is expansion of agriculture into forested watersheds.

14.3 Framework for Evaluation

In the foregoing section, it was argued that humid tropical resources are being degraded at a very significant and accelerating rate and that the process would have taken place with or without existence of the centers. The

question to be addressed is : how much of the process of degradation, restoration or amelioration is in some measure attributable to the activities of the international centers?

If any light is to be shed on this question, the needs are for: some assessment of the performance of the ecosystem before and after the existence of the centers and, an assessment of how things might have been in the absence of the centers. Figure 14.3 offers a conceptual interpretation of the trends in environmental quality. Curve W represents what happened with the CGIAR in place and curve WO what is likely to have happened without it. The shaded area abc between the curves is the environmental quality benefit attributable to the CGIAR. If these curves were to be reversed, the abc would constitute an attributable cost. The curve WP represents a level of protection that might have been achieved by a different CGIAR strategy, i.e., the area abd would constitute the unrealized potential benefit. The challenge then is to attempt to quantify abc and abd. The management of resources can be judged by four performance indicators - productivity, stability, sustainability and equity. Productivity might be measured by physical yield or the internal rate of return; stability by the variability of production: sustainability by the ability to recover productivity after unpredictable disturbances; and, equity by the distribution of costs and benefits derived from use of the ecosystem (Conway 1984).

Conflicts inevitably arise where there are various objectives, as illustrated in Table 14.1 by the indicators for four technologies applied in the humid tropics.

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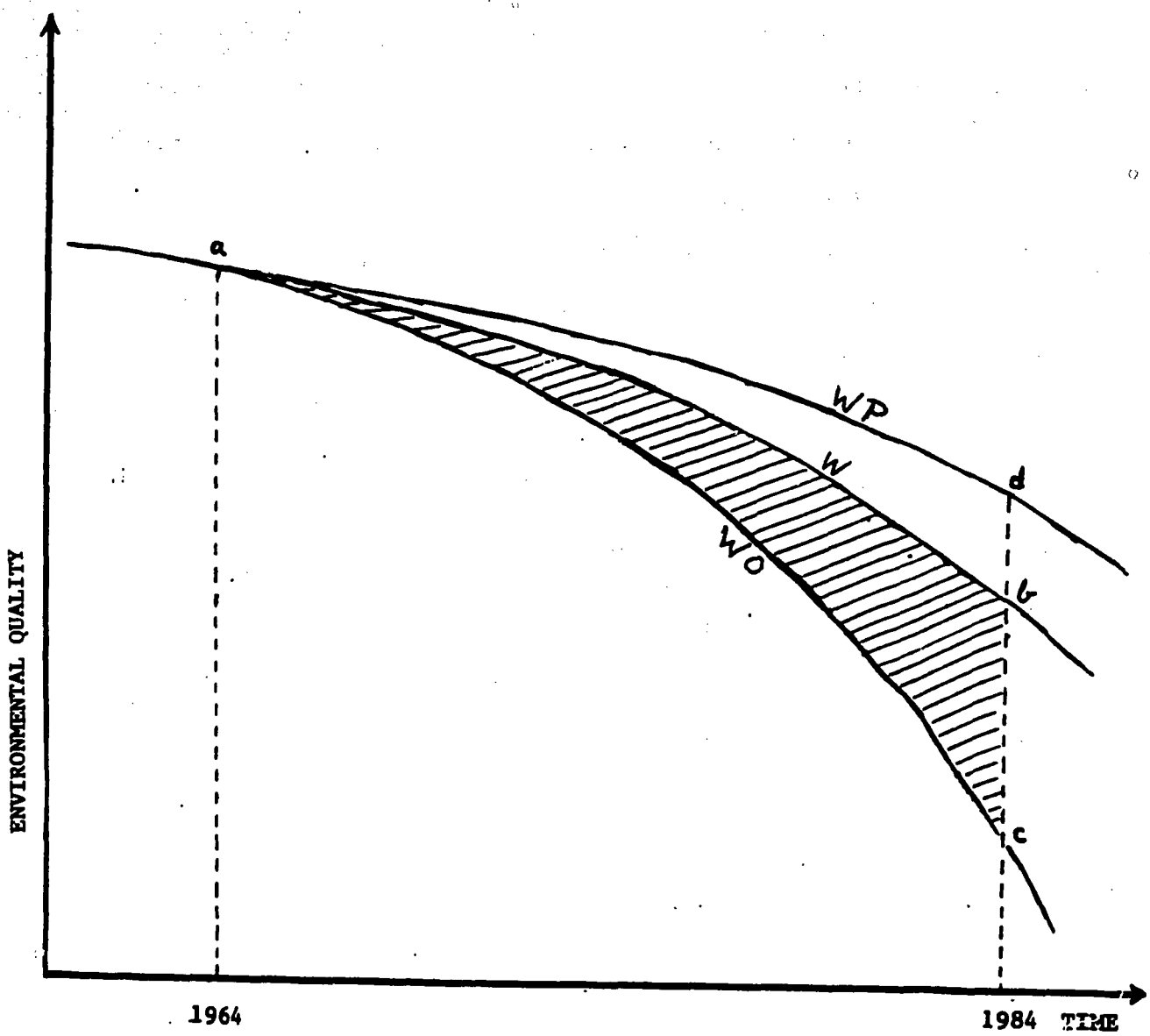
Figure 14.3

Tropical Environmental Quality Scenarios
Under Two Assumptions on CGIAR Impact:
a Conceptual Framework,



WO = without CGIAR
W = with CIGAR
WP = potential with alternative CGIAR strategy

In order to influence the course of development of the humid tropics, it is necessary to understand the dynamic interactive process between the actors involved in their use of organization, power and values and their compatibility with the chacteristics of the ecosystem. In the present context, there is a new "actor" in the system--the centers, whose task is to generate and disseminate materials and information which, if applied, can be expected to change system performance as measured by one or more of the indicators. This requires a "coevolutionary" view of agricultural development (Norgaard 1984).

Table 14.1 Management performance under selected technology options in the humid tropics

Agricultural technology	System performance indicator			
	Productivity	Stability	Sustainability	Equity
Slash-and-burn	Low	Low	High	High
Traditional crops	Medium	Medium	High	Medium
High technology	High	Low	Low	Low
Compromise intermediate technology	Medium	High	High	High

Conway (1984, p. 11).

These general concepts may be used to examine the centers' strategic and tactical options toward development in the humid tropics. Strategy is dependent on the relative weight assigned by the centers to the four objectives. These determine who and where the prime targets are for

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application of the research. Tactics comprise the measures for reaching the target population and areas - germplasm, management, policy analysis, outreach, etc. This framework is used for the evaluation in the following section.

14.4 Potential Impact of the Centers on the Use and Management of Renewable Resources in the Humid Tropics

It is perhaps ironic that a preeminently scientific establishment such as the CGIAR should be evaluated on its possible role in amelioration or aggravation of environmental damage in the humid tropics. Why should a supplier of "intermediate goods" to national programs be concerned about the environmental consequences of "consumption" of such goods by governments and private entrepreneurs over which it has absolutely no control? The centers' main activities lie in the genetic improvement of selected tropical crops. To the extent that the centers develop varieties that are higher yielding, drought and disease resistant, early maturing, insensitive to daylength etc., it may be argued that there is little basis for correlating change in the environment with those varieties; in other words, the technology has at a minimum no impact on the environment and may possibly be favorable. However, to the extent that the centers are increasingly involved in national research or agricultural policy, and influence soil, crop and livestock management and farming systems, there is room to insinuate a potential negative or positive role.

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The approaches adopted by the various centers raise a number of issues that must be dealt with in assessing the nature and extent of environmental change (negative or positive), which in turn may be attributable to the output of the centers. The primary issues are: self-provisioning vs commercial products, low- vs high-input technology, fragile vs robust ecosystems, sharp focus single-track objective vs a broad-based systems approach: wide adaptability vs targeting; direct research vs research methodology orientation, germplasm vs management, and centralized vs decentralized decisions on center activities.

14.4.1 Self-provisioning vs commercial products

By focusing on rice, maize, beans, cassava, beef and milk, the centers have opted for tropical products in part of relevance to the "self-provisioning sector". However, the performance criterion seemingly most valued by the centers is the gross increase in production attributable to the varieties or management practices they have developed. Where the measure of success is output or gross value, it is logical that the centers should not be averse to the implementation of research results in the best favored agroclimatic conditions and by those classes of farmers who are in the best position to provide the management skills and inputs required to realize the yield potential. Under these circumstances, it is to be expected that the centers would use some resources to provide additional information to institutions that can implement promotional policies influencing adoption of modern varieties. The consequences for management of humid tropical lands arising from this approach hinge on the question of whether or not self-provisioning farmers do more damage to the environment than commercial farmers. Unfortunately, no clear answer exists.

Self-provisioning farmers with an adequate area to enable long enough bush-fallow for recovery of soil fertility, are the least damaging. As population pressure builds up, bush-fallows usually are shortened, and damage increases exponentially. Where land is prepared for small farms under government projects using mechanized forest clearing, (as in Indonesia), damage may be attributed indirectly to the small-farm sector. Further, as population pressure increases, self-provisioning farmers are often forced on to progressively more marginal, steep lands where annual cropping is not sustainable. Large-scale farmers have the potential to cause even greater on-site damage, where mechanized land clearing and subsequent tillage is generally a prerequisite. With adequate capital, physical productivity may be sustained: however, financial criteria may dictate abandonment of a degraded asset, as has occurred with a number of the large-scale schemes promoted by state subsidy in the Amazon over the past 15 years.

Given the range of large- and small-scale users of center products in the humid tropics, what options are open to the centers if environmental damage were to be a decision variable? If modern varieties and accompanying management packages are more or less environmentally neutral (chapter 8 and 13), the issue of strategy arises only where technologies have a potentially favorable impact, e.g., the CIAT management packages in the Llanos of Colombia or IITA's work on land clearing and minimum-tillage. Small producers may not have access to the inputs or management skills that would enable them to benefit from the new sustainable technological packages and thereby to reduce damage to soil and forest resources.

14.4.2 Low- vs high-purchased-input technology

Humid tropical zones in much of the world are characterized by isolation from markets and input supplies, and by notoriously nutrient-deficient soils. The exceptions are the volcanic and alluvial soils and the densely populated areas of S.E. Asia used for intensive rice production. The development of fertilizer-responsive varieties may have only limited applicability in much of Latin America, Africa and the outer islands of Indonesia and the Philippines. The impact of technology based on either high or low levels of intensity of use of purchased imputs on the status of tropical renewable resource productivity, stability and sustainability is conditioned by the relative fragility of the area in which the technology is applied.

14.4.3 Fragile vs robust zones

In assessing the potential impact of center research on management of tropical resources through development of different production systems in fragile or robust resource situations, it again comes down to the performance criteria applied. By focusing research on the better tropical soils and intensive irrigated crops with use of high-input technology, the centers can maximize their performance record measured by additional output. At the same time, by avoiding the fragile low-fertility marginal soils, they may claim immunity from blame for any damage that may result from agricultural activities on such soils. Development of high-input technologies for such soils would clearly make them vulnerable to the criticism of promoting productivity at the expense of stability and sustainability. Also by focusing

on the more robust ecosystems, such as the savannahs and cerrados in Latin America, they can minimize association with the degradation issue, regardless of whether high- or low-purchased-input technology is the focus.

On the basis of the three questions discussed above, the issue resolves itself into one of multi-purpose targeting (see also chapter 15): to reach specific beneficiary groups, e.g., subsistence farmers: to increase total volume and consumption of basic food commodities: and, to achieve the foregoing within some acceptable limits of environmental degradation. The issue is illustrated in Table 14.2. Eight situations (target groups) are identified according to ecosystem, location with respect to markets, and size of farm. The options open to the centers are to focus on one or more of these situations with high or- low-input technology, or both.

Table 14.2 Options for targeting small and large farms in fragile and robust tropical environments through technology of different impact intensity.

Humid tropical environment	Input intensity of the technology			
	High		Low	
	Size of farms		Size of farms	
	Large	Small	Large	Small
Fragile				
Near markets (S. Nigeria)	1[a]	2	9	10
Remote (Amazon)	3	4	11	12
Robust				
Near markets (Java)	5	7	13	14
Remote (Llanos)	6	8	15	16

[a] Numbers in the table are referred to in the text as "situations".

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In terms of increased food and short-run financial viability, the focus would be high-input technology applied in situations 1, 2, 5 and 7. Sustainability as a criterion might suggest expanding to a low-input focus, i.e., situations 9, 10, 13 and 14. It is to be assumed that a high-input approach in remote areas, whether robust or fragile (situations 3, 4, 6 and 8), is ruled out on financial grounds. The remaining questions then become whether to address remote areas, fragile and/or robust, through low-input technology - situations 11, 12, 15 and 16. From the viewpoint of environmental damage, the critical areas are situations 11 and 12, particularly situation 12. In the absence of other options, subsistence producers tend to expand on to steep fragile lands in the tropics, thus becoming a major source of damage. Low-input technologies may enable a more sustainable production system in this case. The gain would be a reduction in the exhausted land area and reduced downstream effects, neither of which are generally considered as criteria for center performance.

The concept of "low-input" is relative : generally, some external inputs must be applied if the farming system in fragile ecosystems is to be sustainable, e.g., 25 kg/ha of nitrogen a year on tropical pastures or herbicides in minimum-till cropping. Thus, adoption of such technologies is to be expected in situation 11 rather than 12. A similar situation would hold in remote robust areas, where adoption would be greater in situation 15 than in 16, e.g., CIAT's program in the Colombian Llanos.

14.4.4 Single-purpose vs broad-based systems approach

The early success of the centers is frequently attributed to single-minded attention by teams of dedicated scientists to systematic removal of production constraints in a very limited number of food products. Moving "downstream" from the germplasm developed with advantageous production characteristics, the centers have become involved in cropping systems, e.g., maize-based, rice-based, etc., where a start may be made with varieties followed by progressive moves to the use of fertilizers, water conservation and other cultural practices in a rotation. In this process, the centers seek to improve performance of the humid tropical agro-ecosystem in terms of productivity and stability, but not necessarily in sustainability and equity. It can be persuasively argued that it is not the role of commodity-specific centers to concern themselves with overall system performance. However, the question arises as to whether or not individual centers should develop guidelines based on a systems view of the conflicts and management issues that arise in intensifying the use of renewable natural resources in the humid tropics. These might make their research more relevant to the sustainability issue. In addressing this question, it is necessary to consider sequentially the remaining four inter-related issues - wide-adaptability vs targeting, research vs research methodology, germplasm vs management, and centralized vs decentralized decisions.

14.4.5 Wide adaptability vs targeting

In the humid tropical environment, the wide-adaptability approach has been successful for irrigated rice. In most of the other breeding programs,

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emphasis has been placed on targeting for specific ecosystems and types of producers. Even in rice, recurring pest and viral attacks have placed heavy demands on breeders to stay one step ahead of potential disease outbreaks. Targeting of research may well be essential to address resource management questions that involve multiple objectives. Use of targeting to reduce the negative environmental effects of instability and unsustainability, questions arise of how finely-tuned the targeting should be, and which institutions (national and international) should undertake the research to meet the target specifications. These questions are addressed further in chapter 15.

14.4.6 Research vs research methodology

The targeting issue leads to the question of the relative weight to be assigned by the centers to undertaking the research vs a focus on research methodology and networking to support national research programs that should be expected to evolve a holistic approach to resource management, taking account of technological options, institutions and cultural endowments under particular resource (natural, human and capital) situations.

14.4.7 Germplasm vs management

As the centers are drawn away from the germplasm focus into management, their work becomes progressively more site-specific. Given the nature of tropical crops and the heterogenous characteristics of the rainforest ecosystems, the tendency is to become much more heavily involved in management. It is axiomatic that a management focus that addresses three, if not the four, measures of performance from the humid tropical agro-ecosystems is a critical element in reducing environmental damage.

Two questions arise with respect to centers' strategies. First, no satisfactory indicator has been devised to measure a center's performance on the management side. For instance, the work carried out by IITA on forest clearing has thoroughly documented the damaging effects of certain methods on productivity and sustainability. However, there is no evidence to demonstrate if, or to what extent, these research results have been taken into account by decision makers in selecting clearing methods. Similarly, there are no statistics on adoption of minimum-till practices, which could then be translated into indicators of performance in terms of productivity, stability and sustainability. In contrast, the germplasm improvements at several centers have resulted in substantial identifiable effects (chapter 6). Second, since the problems of multi-objective development of agriculture in the humid tropics tend to be more site-specific than other ecosystems, there is need for more finely honed breeding which makes greater use of indigenous germplasm and research, with feedback from implementation, into interactions between the natural system and decison structures in evolving and applying production technologies (Norgaard 1984). On the surface, it appears unlikely that this task could be effectively undertaken by the centers. If this is true, and the centers are concerned about their role in management of tropical resources, the question is how may the centers structure their research, outreach and network capabilities to service best, and accumulate and disseminate knowledge from, national research institutes.

14.4.8 Centralized vs decentralized decisions

The past three issues discussed all bear on the question of whether or not the centers could make a greater contribution to development of tropical

agriculture by introducing a greater degree of strategic planning at the level of the CG itself. Should there be a more explicit formulation of research policy at the inter-center level? Thus far, it has been argued that the centers' work related to development of the humid tropics has focused heavily on productivity and to a lesser extent on stability and sustainability. While they have worked on management questions bearing on the latter indicators, there is little evidence on how the research has contributed to achievement of this objective.

It was suggested above that development of tropical forest areas for agriculture is unnecessarily destructive: sustainability is not being used as a decision criterion in the process; and destruction on a vast scale is reducing the natural productive capacity on millions of hectares annually. Given this on-going process, the CGIAR can take one of two positions - either, the problem is rooted in national political and cultural institutions and therefore is wholly outside the "area of influence" of international agricultural research or, the matter is of concern to the CGIAR and research and outreach activities should be designed to address more specifically this concern. The latter approach would require a system-wide examination of the options open for introducing sustainability as an explicit performance criterion for concerned centers. A fundamental question here is - from whence might come the demand for such an approach. As indicated, the concern about degradation of the humid tropics appears to be much greater, and more vocal, in non-tropical than tropical countries. If this is true, strict adherence to client demand is likely to result in selection of the former approach.

14.5 Synthesis

The initial question is whether the CGIAR should use environmental quality as one of the criteria for judging its performance with respect to agricultural production in the humid tropics. It was argued in section 14.3 that performance should be judged within a systems context of renewable resource management where the indicators are productivity, stability, sustainability and equity "outputs" from a system that is conditioned by center products. It is taken for granted that the evidence on short-run productivity is overwhelming, and it is assumed here that equity is unrelated to resource degradation. Accordingly, the evaluation addressed the stability and sustainability questions in terms of indirect macro impacts and direct micro impacts.

Without modern varieties, production of rice and maize in the 90 countries with humid tropical lands may have been 20 to 30 Mt less than it is. To have made up this shortfall from nonirrigated lands with traditional varieties and management packages would have required an additional area under cultivation of the order of 20 to 40 million ha. Estimates of incremental quantities of cassava, beans, cowpeas, beef and milk attributable to CGIAR-related activities have not been made. The area in these crops and pastures in the humid tropics in 1982 was about 1000 million ha. If a 10 percent increase in output due to work associated with the centers is arbitrarily assumed, the additional area needed to substitute for this

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technology would be 100 million ha. These figures do not imply that, without the centers, an additional 100 million ha would have been cleared from tropical forest over the past 15 years. In fact, given the nature of traditional tropical agriculture and fertility decline, the area cleared to make up such a short-fall would have to be considerably more than 100 million ha. In reality, it is to be expected that total production would have been much less and increases would have been forthcoming from irrigated areas and other sources of technical change.

However, there can be little doubt that, in absence of the increment attributable to modern varieties and improved management packages there would have been substantially more pressure on the tropical land frontier. In addition, since reduction in supply of these staples would have increased prices, it may be assumed that marginal areas on the forest frontier would have become viable prospects for short-run development with negative long-run effects on sustainability of the resource base. With levels of increase in production of the order of those suggested here, it would be reasonable to expect the rate of land clearing to decline as the impact of center-related technology became significant in the 1970s. However, in 14 countries accounting for about 75 percent of nonirrigated farm lands in the humid tropics, there was no change in annual additions to area over the period 1950-1982. This suggests that the rate of clearing would have accelerated after 1965 in the absence of the centers.

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It is considerably more problematical to speculate on the extent to which varieties and management practices developed by the centers have contributed to consolidation of agriculture on traditional slash-and-burn areas. As indicated in section 14.4, this is a two-edged sword - some of the area in bush-fallow may be abandoned and thereby allowed to revert to secondary, or eventually climax, forest - or, alternatively, the new production packages may offer the prospect of short-run gains that encourage both self-provisioning and commercial farmers to exploit land that otherwise would be considered marginal, with serious irreversible destruction of soils after two or three years. Centers' liability for amelioration or exacerbation of damage is directly related to the extent that activities are oriented "upstream" or "downstream". On the exacerbation side, there is no evidence to support the position that damage to the tropical resource base (measured by sustainability), as a result of expansion and intensification of land in agriculture, is worse as a result of the centers' activities relevant to crop improvement for these lands, i.e., the area abc in Figure 14.1 is, at worst, zero. This being the case, the question becomes: could or should the centers have done better (i.e., move curve W towards curve WP in Figure 14.1) with a different strategy and tactics. The options may be examined in terms of the eight issues discussed in 14.5. As a point of departure, it is taken that gross production and productivity are necessary but not sufficient indicators of the success attributable to direct application of center products. The strategic issues are subsistence vs commercial products and fragile vs robust zones. The remaining six issues are tactical.

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On the question of strategy, there can be little doubt that the subsistence-food-crop approach is highly relevant to both economic development and alleviation of poverty. Thus, inevitably, the centers are placed in the position of dealing with tropical crops, with the exception of pastures, that are more environmentally damaging than commercial products such as sugar, coffee and tree crops. This is an "occupational hazard" that may be used to imply that the CGIAR should either diversify into commercial crops or substitute them for subsistence crops. The strategy with respect to dealing with robust vs fragile ecosystems is less easy to assess, and is interrelated with a number of the tactical issues (low purchased inputs, targeting and management). It is often argued that, if the centers are to have credibility, they must work with the less risky areas and must address those institutional/physical situations where their packages are bound to work. It is this credibility that enables them to move upstream and work with national entities that tend to judge their own performance by the same criteria. National policies have given little weight to management of resources in fragile ecosystems, as manifested by the generally weak institutions concerned with such areas. At issue for the CGIAR is the tradeoff between reduced credibility with powerful national entities and added support to weaker agencies working with fragile systems, if some resources were diverted to breeding, management and outreach for such systems.

If sustainability is included among the CGIAR's performance criteria in support of tropical agriculture, the tactical issues all become interrelated. One key question is how many center resources should be diverted to "upstream"

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and "downstream" involvement. Upstream, the concern is with helping to generate the national institutions and policies which, in turn, create effective demand for center packages that yield quantifiable measures of performance, e.g., crop area erosion rates, potential production capacity preserved. A major constraint here is the difficulty of establishing a direct relationship between a center management package and the eventual outcome. The centers may be tempted to follow tactics of germplasm improvement rather than management, high-purchased-input rather than low-purchased-input technology, and a narrow focus rather than a systems approach. The work of IITA on the effects of various forest clearing methods on agriculture's productivity and sustainability and sedimentation illustrates the issue. Another case is CIAT's work on management of cassava on sloping lands which demonstrates that use of minimum till, fertilizer placement and pasture barriers will reduce erosion from 100 to 5/t ha a year. No way has yet been devised to measure the effect of this research on operating and policy decisions. If such a measure existed, and sustainability was a matter of real concern to the international community, IITA and CIAT may become more interested in a reallocation of resources to upstream activities.

The tactic of moving downstream to learn more from farmers on what works, adoption, etc., is interrelated with selection of tactics such as - management rather than germplasm, targeting rather than wide adaptability, a focus on research methods rather than center-based research, and a systems approach rather than a single-purpose orientation. For the reasons given above, most of the results of these tactics are difficult to quantify.

The nature of resource management demands targeting with precision that is far beyond the existing or even the potential resources available to the international centers. The question arises as to how can the centers use their very limited resources to maximize their contribution to multi-objective resource management in the tropics, using as the point of entry their established reputation in a few subsistence crops. The key tactic here would appear to be adoption of a systems approach (in identifying critical physical, institutional and economic constraints) to strengthen the role of the centers in institutionalizing research methods where they act as vehicles for accumulating and disseminating information, and for quality control. This would involve moving both downstream and upstream. Any move upstream must build on a solid record of achievement that is probably most evident in the older crop-specific centers such as IRRI and CIMMYT. Another characteristic of much of agriculture in the tropics is remoteness, which suggests a low external input tactic, e.g., with emphasis on breeding for disease and drought resistance, efficiency in fertilizer uptake and biological nitrogen fixation: limited till: and water conservation.

The final tactical question that cuts across all the issues discussed above is centralized vs decentralized decision making in the centers and the TAC with respect to choice of tactics to be adopted in addressing tropical agriculture. The CGIAR and its partners in research cannot be expected to revolutionize the scientific and institutional basis for achieving highly productive, stable, sustainable and equitable agriculture in the tropics. Bunting (1982) has posed the challenge as follows:

"Unless there is sufficient volume of effective demand, a reliable output delivery system, a sufficient supply of the necessary resources, including knowledge, in the hands and minds of producers, and a sufficiently coherent and effective policy and administration internationally, nationally and locally, the HYV technology is hardly likely to succeed on the vast scale we need it. Research, new production technology, education, extension, inputs and credit, the hallowed toolkit of the western developer, may, or may not, be necessary conditions for agricultural change, but they are far from sufficient."

If the premise of this chapter is accepted, that stability and sustainability of agriculture in the humid tropics should be criteria used by the CGIAR in judging its performance, it may be asked from whence comes the strategic long-term thinking on selection and design of tactics to be used within the global context posed by Bunting? This suggests some degree of centralized decision making, which clearly runs counter to the highly focused, decentralized philosophy which has been the engine of the CG system's success to date.

14.6 Coda

* Without the modern varieties, total food grain production would have been much less. In their absence, there would have been more pressure on the tropical land frontier. Over the past decade, perhaps as much as ten million extra hectares of forest would have been felled.

* Relieving pressure on the land may have helped to consolidate some areas of traditional slash-and-burn agriculture.

* Conversely, new technologies that lower unit costs of production may have led to some extension on to land where production in the absence of new technology would not have been viable. This can lead to irreversible soil destruction.

* Choice of basic food crops has predetermined that the centers are working in areas of greater environmental fragility than would be the case if they were working on, say, major export and tree crops.

* Attention to risky areas may involve some loss of impact on output from favored high producing stable areas.

* Any specific attention to sustainability would involve broadening the criteria by which the centers are judged: measures of sustainability (preservation of productive capacity, lower runoff rates) would need to rank with the spread of improved varieties and the short-run increase in output as measures of performance of the system.

* An issue now faced by the centers is whether evidence on apparently irreversible damage to renewable resources in the humid tropics dictates a systematic evaluation of why and how to incorporate the sustainability

dimension into their work. Given the physical, social, economic and institutional complexity of renewable resource management in the humid tropics, it is not readily apparent whether the centers have the resources to undertake research and to seek greater involvement with the wide range of national institutions that impinge on sustainability of an ecosystem under agricultural exploitation. The issue is of sufficient importance to warrant those centers involved in tropical crops undertaking an assessment of options for research that might make an effective contribution.

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15 EDAPHOCLIMATIC TARGETING

15.1 Introduction

As a prelude to considering research on farming systems and to complement the foregoing chapters on some important technological research components, this chapter is addressed to environmental classification with a view to targeting of and defining relevance of agricultural research at the centers. It is based on a longer report prepared by Robert Brinkman (1985).

15.1.1 Environments

The environment of a crop, a land use or a farming system has physical, chemical, biological, social, economic and infrastructural aspects. Only the first three fall within the terms of reference of this chapter. The environment varies across space and time. Optimal varieties and management methods are similarly variable.

The site-season (or the site-year) can be considered as the basic unit of environment. It allows the study and description of:

(a) the stable environmental aspects of a site (e.g., landform, available water capacity of the soil, exchangeable aluminum levels in surface and subsoils);

(b) the aspects that vary with the seasons and fluctuate with time (e.g., temperature, rainfall over the crop season; and

(c) the actual incidence of aspects that may fluctuate from year to year (e.g., of downy mildew, plant hoppers, cyclones).

Viewed in this way, the number of environments is essentially infinite, but only part of the variation is of practical importance. Environmental information is therefore summarized, classified and mapped at different levels of generalization. The resulting classes and maps range from very broad (e.g., humid tropical lowlands, tropical intermediate altitudes) to detailed (e.g., calcareous silty or loamy soils, seasonally flooded to less than 0.5m depth).

Experimental results that are consistent across years and across many sites (e.g., the relative performance of certain varieties in favored environments) can be applied with confidence over the range of environments covered by the experiment. Where results vary across years or sites, such confidence can only be derived from a relation of experimental results with environmental variables at the sites, combined with similar environmental information for the areas where application is intended.

Environmental variables determining the applicability of research findings may be of many different kinds. For crop production, for example, they may include the incidence and range in severity of disease, the incidence and length of drought periods in a rainy season, the soluble ferrous iron and exchangeable nutrient cation contents; or for post-harvest storage or drying they might be the temperature regime and relative humidity, or solar radiation and frequency of rainfall events.

15.1.2 Mandates and expertise

Crops generally grow in environments having many aspects not under human control. Some aspects of the environment can be controlled or modified, at a cost, by one-time land improvements or recurrent management measures. One of

the ways to do without or to minimize the need for such modification is to choose crops that do well in a specific environment; another is to modify the crop so that it is better adapted to the nature of the given environment or better armed against its stresses.

Much of the work of the centers is concentrated on the development and supply of genetic materials with desired qualities for further breeding, selection or direct application in developing countries. Other research deals with methods of management or land improvement to raise or stabilize benefits and increase the efficiency of inputs (e.g., pest management, multiple cropping, fertilizer efficiency).

All these activities require knowledge about the nature of the environment in which the research results are obtained and knowledge about the location and extent of the environments for which the results are relevant. The conviction that such knowledge is necessary is widespread but not universal in the international centers.

The system of centers as a whole has the expertise to develop environmental classifications that are needed for targeting genetic materials as well as for tuning land management and improvement methods to environments. The system can also muster the expertise to characterize both the stable and the variable environmental features of a site that influence the performance of genetic materials or the success of methods tested at that site. Part of these activities have already been undertaken and the results are being used, mainly within centers or individual programs.

Some centers have embarked on describing and mapping the broad physical environment in their most immediate parts of the world, e.g., CIAT in N. South America or IITA in humid and semi-humid W. Africa, on the basis of existing information with some additional field work. To enable a more specific response to different questions about environments, CIAT has entered basic environmental data for several thousand sites into computer storage and made them accessible through a geographical data-base management system devised and developed at the center. IRRI has collected a data base of climatic information on south and southeast Asia, combined this with information from the Soil Map of the World (FAO 1974,1976) and data on the location and extent of the upland rice cultivation, in order to define breeding and selection objectives and to identify representative screening sites for upland rice.

More contacts both among centers and with others will be needed to speed up the wider application of practical and low-cost methods of data collection and management, as well as to widen the circle of users once environmental data sets have been collected and made accessible through a management system.

Matching genetic materials, management and improvement methods with environments is a continuing activity rather than a once-only project. The centers are aware of this and act accordingly, within sometimes quite severe limitations of financial and personnel resources.

The methods, approaches and insights for optimal adaptation of the research to environments that are mentioned in later sections are presently used, are being developed or are being considered by the centers or at least by researchers in one or some of them, except where specifically attributed to others.

15.1.3 Different perceptions of environments

For purposes of plant breeding, the world in which a crop is grown is often perceived in terms of a limited number of distinct mega-environments, generally characterized in broad climate terms. Regions distinguished at a similar level of generalization, but with some soil differences also taken into account, have been termed agroecological zones and edaphoclimatic zones. Both spatial and temporal variability are recognized within these mega-environments. Part of this variability is ascribed to the incidence of specific biotic or abiotic stresses, part is not explained.

Where large regions within a mega-environment can be characterized by the prevalence of different combinations of stresses, these are used to subdivide the mega-environment into macroregions. Plant breeding nurseries can then be targeted to a mega-environment or a macroregion. They may also be targeted to a stress or a combination of stresses which occurs extensively but is not restricted to a macroregion or a mega-environment.

In contrast, the environment of farming systems research may be perceived as a mosaic of land types, with variation at a detailed scale across the landscape, within rather closely defined climate zones. A recommendation domain or a microregion is an area with a similar land type or recurrent combination of land types, as well as social, economic and infrastructural conditions faced by farmers.

A whole farming system can generally be applied only within fairly narrow environmental limits, since it is restricted by the environmental limits of each of its components. A single component of a farming system is

usually applicable over a wider range of environments, and typically forms a part of more than one farming system. Viewed in this way, a variety or a clone is such a component, with rather wide environmental limits.

In plant pathology or entomology, the environment is seen in broad terms or in detail, depending on the degree to which relationships have been recognized between pest or disease incidence and stable environmental features that can be represented on a map or readily observed in the field.

15.2 Plant Breeding

The international centers concentrate much of their effort and resources on the continual improvement of crop germplasm. Improvement is in terms of potential yield, fertilizer responsiveness, resistance to or tolerance of pests, diseases and abiotic environmental stresses.

For farmers, the choice of the clone or cultivar that gives the highest yield under particular farm conditions generally entails low costs compared with other measures to increase net returns, such as fertilizer application, weed control, chemical plant protection, drainage, irrigation, etc.

Plant breeders, especially when seeking to improve grains and grain legumes, tend to select lines with yield stability and wide adaptability to environments, as well as high average yield, resistance against specified diseases, and suitable plant type or product type (e.g., seed color). Yield stability across years is sought because of the largely unpredictable variation in the environmental characteristics of a site from one year or season to the next. Broad adaptability across sites is sought to minimize the

need for a multitude of varieties, each with a narrow environmental niche, usable locally on only a small area.

A universal clone or cultivar would be resistant against a wide range of pests, diseases and other environmental stresses, daylength insensitive, heat and cold tolerant, tolerant to drought, and to oxygen deficiency in the root zone (waterlogging), adapted to low fertility but with a high fertilizer responsiveness, and tolerant to a range of toxic conditions in the root zone. Since this ideal cultivar cannot be produced, choices must be made in plant breeding, and cultivars or clones are designed and selected for resistance to or tolerance of combinations of stresses prevalent in specific environments.

Information from multilocation trials generally comprises yield, crop phenology and incidence of major diseases and pests, but environmental information for the sites often comprises only latitude, longitude and elevation above mean sea level. For some experiments, at some locations, reports are also made of site variables such as rainfall means or actual daily rainfall data, temperatures, sun hours or solar radiation, and soils data such as available P or K. The environmental data generally are not used in the statistical analysis, however, and as a result, the differences in site mean yield (the environmental main effect) sometimes remain unexplained.

Because of the policy of breeding for wide adaptability, particularly in several grain crops, the differences between lines tend to show a degree of consistency across locations. At high-yielding locations in particular, the same few lines tend to be among the top performers. The low-yielding locations are often "poor predictors", in the sense that the relative performance of lines shows greater variation between low-yielding locations

than between high-yielding ones. This is because of the wide variety of reasons for poor yields. These may, for example, include drought, low solar radiation, different nutrient deficiencies, toxicities, poor plant establishment, weed competition, and incidence of different diseases or pests. If the reasons for overall poor performance at a location are known, high-yielding lines at that site may be taken to have a degree of resistance or tolerance to those stresses. Such indications are sometimes not included in the reports or in the further analysis of multilocation trials, however.

In root and tuber crops, the situation seems to be similar in so far as a small number of clones generally yield best or above average consistently across sites, but there tend to be greater differences in required resistance spectra between agroecological zones.

15.3 Pests and Diseases, Distribution and Dynamics

Some pests or disease agencies can be transported rapidly by wind: up to hundreds of km a year or over the period of a single weather event, as with the case of locusts. Global or continental circulation patterns may thus be of main interest for the spread of a strain or biotype. Climate, mainly through temperature and humidity, influences the general incidence and severity of pests and diseases. Specific outbreaks seem to be determined mainly by individual weather sequences, in combination with the continuous or intermittent availability of the crop or other hosts and with the entity's own life cycle. In some cases, soil differences play a part (e.g., Xanthosoma root rot in poorly drained, clayey soils or cassava root knot nematode in continuously moist soils).

Pest and disease pressures thus vary in nature and severity with place and time. They depend, in ways that are only partially quantified, on climate and the actual sequence of weather events, soil hydrology and other soil physical and chemical conditions, the spatial and temporal distribution of the host crops in an area around the studied site, the resistance or tolerance of the cultivar at the site and in the surrounding area, and the nature and intensity of past crop protection measures.

This complicated, interdependent set of relationships has been modeled for few crops in few environments only, mainly because of the time and money needed to collect the extensive data sets on which to base identification of relationships, estimation of parameters, and validation of models. Results from successful models are used by farmers, e.g., in England and the Netherlands to time their crop protection measures for potatoes.

Similar but less quantified information forms part of the Florida agricultural information retrieval system, the approach of which is being adapted in IRRI for training purposes. The integrated pest management methods developed by several centers are in part based on similar information on the dynamics of pest incidence. Thus, the variability of the environment over time is taken into account and used.

With the introduction or rapid expansion of a new crop or cultivar, a "holiday" period may occur, during which potential disease and pests are still absent or negligible. This state of affairs may end by an epidemic or by a more gradual buildup of disease and pest pressures, initially in the absence of natural predators or other controls. Initial success in introduction experiments therefore is no guarantee of continued apparent immunity, as shown

by the sometimes alarming speed with which new cultivars are needed to replace older ones in defense against fungus diseases such as rust. To guard against severe problems arising a few years after cassava introduction into new areas in Mexico, for example, CIAT recommended maintaining a broad germplasm base with several different lines under multiplication, as well as a careful study of changing disease and pest populations during the multiplication period.

Once general levels of certain disease or pest pressures are correlated with environments, or with certain environmental variables, even initial species introduction into new areas may be pre-tested for resistance against the most serious of the likely threats.

For example, differences between pest pressures on pasture species in different environments are clear from Table 15.1. In cassava, common bacteria blight and superlongation are severe only during prolonged rainfall periods; Phytophtora and Pythium root rots are most prevalent in poorly drained, heavy soils; the concentric ring and white leaf spots occur where rainy-season or winter temperatures fall below 18o°C (Lozano et al. 1980). An example of a broad, world-scale, classification of edaphoclimatic zones for cassava, with emphasis on pest and disease incidence, is shown in Table 15.2.

The effect of pathogen or pest on a cultivar depends on natural and man-made aspects of the environment as well as on the kinds and amounts of management inputs. The latter are influenced by the economic, social and infrastructural conditions under which the farmers operate. These conditions can often be taken as reasonably uniform for strata of farmers within countries or major regions within countries.

Table 15.1 Importance of insect groups in relation to the degree of damage caused to some legumes and grasses in various ecosystems

Pasture species insect groups	Ecosystem and sample locations			
	Well-drained isothermic savanna cerrado	Well-drained isothermic savanna, llanos		Seasonal semi-evergreen forest
	CPAC Brazil	Carimagua Colombia	El tigre Venezuela	Pucallpa Peru
Stylosanthis				
sucking insects	3	3	3	3
leaf-eating insects	3	1	2	3
stem borers	1	1	1	-
budworm	1	1	1	-
Zorina				
sucking insects	1	3	3	3
leaf-eating insects	3	1	2	-
budworm	1	1	-	-
leaf miner	3	1	-	-
spidermite	-	-	3	-
Andropogor				
leaf-eating insects	-	1	-	-
aphids	-	1	-	-
Brachiaria				
sucking insects	3	3	3	3
rasping insects	-	2	-	1

Data from CIAT 1984 Tropical Pastures Program Report, Table 12.

Table 15.2 Edaphoclimatic zones for cassava production and their main characteristics.

Edaphoclimatic zones (ECZ) no.	General description	Representatives	Sites in Colombia for germplasm evaluation and technology testing	Major yield constraints
1	Lowland inputs with long dry season, low to moderate annual rainfall, high year-round temperature	Northeastern Brazil, north coast of Colombia, northern Venezuela Thailand, southern India, sub-Sahelian Africa	Caribia, Fonseca, Media Luna, Nataima, Rionegro	Drought, mites, thrips, mealybugs, termites, bacteriosis root rots, viruses
2	Acid soil savannas with moderate to long dry season, low relative humidity during dry season	Llanos of Colombia and Venezuela Cerrados of Brazil, savanna of southern Mexico	Carimagua	Low soil fertility, drought, bacteriosis, superelongation, anthracnose, Cercospora leafspot, mites, mealybugs, lace bugs.
3	Lowland tropics with no pronounced dry season, high rainfall, constant high relative humidity	Amazon basins of Brazil, Colombia Ecuador, and Peru, rainforests of Africa and Asia	Chigorodo, Florencia	Low soil fertility
4	Medium-altitude (800-1500 m) tropics with moderate dry season and temperature	Medium-altitude areas of Andean Zone, Bolivia, Brazil, Costa Rica Indonesia, Philippines, Vietnam	Caicedonia, CIAT-Palmira, CIAT-Quilichao	Thrips, mites, mealybugs, bacteriosis, mycoplasma, anthracnose, root rots, and viruses
5	Cool, tropical highland (1600-2200 m) areas with mean temperatures of approximately 17-20°C	Highlands of Andean zone and tropical Africa	Popayan	Low temperature, Phoma leafspot, anthracnose, mites.
6	Subtropical areas; with cool winters and fluctuating daylengths	Southern Brazil, Paraguay, northern Argentina, Cuba, southern Mexico southern China, Taiwan	None	Low winter temperature, bacteriosis, superelongation, anthracnose.

Since climate and weather conditions determine the likelihood of damage from many pathogens and pests, a subdivision into homogeneous edaphoclimatic regions makes it possible to develop specific management recommendations against them, as well as to select, or breed and select within such regions for appropriate levels of resistance. For soil-borne or soil-related pathogens or pests, a further subdivision is needed to arrive at homogeneous recommendation domains.

15.4 Agronomic and Farming Systems Research

Farming systems and their components are generally more sensitive to differences in climate, soils and topography than the choice of lines or clones with the highest relative yields. Two examples illustrate this.

In Vertisol watersheds of southern India, different cropping systems are needed for optimum moisture use in adjacent areas with different probability of drought periods in the rainy season, although rainfall totals are similar. Crops and varieties are similar in the two environments.

In the Philippines, rainfall probabilities for the onset and the termination of the rainy season have been used for extrapolation and mapping of areas where certain improved cropping patterns would likely be successful, as well as for fine tuning of the cropping patterns.

15.4.1 Farming systems and components

A successful farming system is an economically and socially viable set of activities and inputs producing benefits from land. Each activity has its own environmental limits, e.g., the cassava crop requires sufficient moisture,

generally from rainfall, and high relative humidity for high yields of fresh tubers, whereas the natural drying process of cassava chips requires much solar radiation and dry weather. Any complete farming system is therefore applicable within a fairly narrowly circumscribed environment. An individual activity may become a part of more than one farming system, and normally has a wider environmental range.

Therefore, farming systems researchers have spent much effort on environmental description and analysis. Once the difference in range of applicability between whole farming systems and components becomes clear, there can be increased emphasis on component research and clearer identification of such components in farming systems, rather than on monolithic farming systems, for ultimate dissemination to farmers.

15.4.2 On-farm research and environmental differences

The variation between yields of the main current cultivars and the best available cultivar or line at a site may be of the order of 10-50 percent. The variation in yields between different management methods has a similar magnitude in some cases but may be far greater. Also, the variation in crop yields between environments often exceeds a factor two. Part of the yield differences between environments is amenable to human intervention by management or land improvement measures. On-farm research, as done by several centers, is designed to identify technically, economically and socially feasible methods of such intervention. The best methods found generally vary between sites. The differences in optimal methods observed between sites then need to be explained in terms of consistent, readily observed or measured site characteristics. If the results of the research are to be effectively spread, the areas with the same sets of site characteristics need to be delineated so

that farmers within them can be approached. Alternatively, the site characteristics required for successful application can be translated into terms or concepts that are clear to the farmers; the results placed within this context can then be made known more widely.

15.4.3 Spread of research findings among farmers

A promising research finding, whether from on-station or off-station research needs to be tested and adapted under farmers' condition. An international center itself can only reach a small number of farmers with a research finding, or do on-farm adaptive research at a limited number of sites. Ideally, national research and extension organizations, in cooperation with a center, adapt and disseminate each potentially successful finding throughout its recommendation domain.

Wherever this is difficult in practice, it may be useful to extend on-farm adaptive trials as widely as feasible, in the most simple design possible, and unreplicated within farms but replicated within villages across farms, for example. This could be done in cooperation with extension organizations or national research institutes or universities, wherever practical.

Such a course of action, variants of which are used in different centers, has several advantages.

- In a short period of time, the degree of success and its variability under farmers' management can be estimated and the limits of the recommendation domain can be tested. Farmers can help define what went wrong.

- Since farmers are active participants in the trials, many more variants will be tested by the farmers than the researcher could have done, and adaptation by farmers may substantially extend the recommendation domain.
- A successful innovation tends to be spread autonomously by contact between farmers. Speed of spread in west Africa, for example, seems to be between about 5 and 20 km/year, in part depending on road connections. The adoption rate within the area where the innovation is known depends on the perceived benefits and the availability and feasibility of the required inputs.
- Local extension officers, whether actively involved initially or in a later stage, can pick up the innovation and use it in their work.

15.5 Description of Environments

15.5.1 Environmental characterization of sites

Experimental sites are characterized to different standards and specifications by the centers and by programs within centers. This is due in part to different requirements, in part also to the different possibilities of environmental data collection by cooperating investigators at the sites. Descriptions generally include latitude, longitude, elevation, planting and harvesting dates, incidence or pressure of major disease, pests and other hazards. In some cases, temperature and rainfall are recorded as well, and in a few cases also evapotranspiration, radiation totals, landform, soil chemical, hydrological and other physical characteristics or soil classification.

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Such environmental data as are available for a site are generally used for a qualitative interpretation of results obtained at that site. For screening nurseries or observational or yield trials, results are related to the known biotic and abiotic stresses at the site. For agronomic or farming systems trials, much attention is paid to the identification of the environmental variables that determine the degree of success or failure of the method or the system tested, and to the estimation of their critical values. These are then mapped in the surrounding area, but not routinely surveyed in homologous environments elsewhere. Examples of effective identification and mapping are the probability of drought periods in the monsoon season, which separates the areas in southern India suitable for two farming systems developed by ICRISAT, or flooding depth in Cagayan valley, northern Philippines, which delimits the area of successful improvements developed by IRRI for a rice-based cropping system.

In multilocation trials where yield and crop phenology data are available for several or many common lines across sites, analysis generally centers on relative yields or on differences from a site index, such as site mean yield or the mean of two standard lines or of the two best lines at each site. Thus, the many kinds of environmental features that may limit yield are assumed under a single yield-related site variable. Differences in results or performance that are not explained in terms of environment (abiotic or biotic stress incidence) cannot be used for extrapolation to other areas, later years or farmers' conditions, but constitute part of the variability (error term).

If the performance of a set of cultivars is analyzed for a cluster of high-yielding sites, a relatively consistent picture emerges, since the sites constitute a relatively homogeneous environment compared with the differences

of lines across sites may also be consistent. Where low-yielding sites with different kinds of limitations are included in the analysis, however, environmental characterization provides essential information to explain the performance of the lines doing best at that site and thus to identify lines tolerant or resistant to specific stresses.

In cases where differences between sites are of the same nature as between years at a site, e.g., in rainfall distribution or temperature regime, stability across years and adaptability across sites may be closely related. Results from such groups of sites speed up screening of lines or clones and testing of other findings, such as cropping systems or elements of these, by rapid accumulation of site-years of experience. In the case that differences between sites are unlike differences between years, for example in nutrient availability or toxicity, adaptability across sites does not provide information on stability across years. Information on the nature of these differences is not always collected.

15.5.2 Classification and mapping environments

For purposes of targeting cultivars, lines or segregating populations to environments, the land areas of the world have been classified into a small number of mega-environments specifically for one or a few crops or crop groups. These mega-environments have been characterized generally in terms of temperature regime (or altitude in the tropics) and rainfall regime (or the associated general vegetation form). In some cases they have been delineated on small-scale, generalized maps.

At a less general level, some of the centers in cooperation with national counterpart institutes have identified, and in some cases delineated,

macro-regions within a country for a given crop or crop group or land use. Macroregions are specified further than mega-environments. Besides temperature and rainfall, the general landforms, availability of irrigation water, in some cases important soil groups, and general social and economic features are indicated. Within such a macroregion, there tends to be a certain set of major constraints to production, and fairly close specifications of qualities and resistances required in a cultivar can be drawn up.

Specific land improvement or management measures, or whole cropping or farming systems, may still not work optimally throughout a crop macroregion. For this, a subdivision may be on the basis of landform units, specific soils, climate differences, and social, economic and infrastructural features. Some centers have developed systematic methods for this, others make the necessary distinctions on an ad hoc basis. Further work is needed to identify rapid, effective methods of characterizing and mapping recommendation domains or homogeneous crop regions at low cost and with a very small proportion of the work having to be done by highly trained specialists (See Feature: Targeting Technology).

15.5.3 Environmental limits of applicability for research findings

Research findings, whether they are new lines or clones, new machines or tools, or new crop sequences or management methods, each have their own environmental limits of applicability. Coincidence of such limits with environmental class boundaries drawn for a different purpose is fortuitous. The more generalized is the map or classification of environment, the more severe the mismatch tends to be. Often, a satisfactory match can be found only at detailed scales of mapping.

FEATURE: TARGETING TECHNOLOGY

The natural conditions for crop production vary widely. As a result, the requirements that must be met by new varieties and husbandry practices are equally broad. It would be prohibitively expensive to develop materials suited to each narrow ecological niche. On the other hand, a single variety cannot be expected to perform adequately across all environments. This tradeoff has to be resolved. Is it to be resolved by selecting one, two or more "typical" environments and producing materials tailored for them? How are these regions to be selected? How extensive should they be? How variable are they? Is it feasible to produce materials for some of those regions? How difficult will it be? What progress can be expected? Over what period of time?

These are the questions facing the centers in their quest for the most productive allocation of their own scarce research resources. They cannot begin to be resolved without better information about the environments. By investing in the acquisition, assembly, displaying and interpretation of data, existing research resources can be made more productive than they would have been in the absence of such information.

There are two approaches to the problem of defining agroecological zones. If there is a relatively complete knowledge of the physiology of the crop, limits to the ranges of environmental factors can be defined. From these it is possible to map the regions of adaptation of the crop. However,

seldom is sufficient known about the effect of these environmental factors on growth nor on the pest and disease relationships. Furthermore, knowledge of the differential response of varieties to zoning variables is inevitably incomplete.

The alternative strategy is to proceed from the geographical distribution of the crop and use the major differentiating variables and varietal reactions. The work of both CIAT and IRRI in rice has followed this strategy.

The Agroecological Studies Unit of CIAT is providing information based on three types of data: meteorological, edaphic and crop systems. This is of special importance to rice in Latin America because of the variability and dispersion of ecosystems and the strong germplasm-ecosystem interactions.

Data on monthly mean rainfall, temperature and humidity have been stored in specially designed computer files for over 46,000 sites in Latin America. Land systems are defined as areas having a recurring pattern of climate, soils and landscape. Cropping systems data include planting and harvest dates, cultivars diseases, pests, yields and associated crops.

These approaches have allowed CIAT to develop an initial grouping of upland rice areas distinguished as favored, moderate and unfavored. Analyses of drought stress periods, soil fertility, and length of growing season have been used to develop a more detailed knowledge of the environmental circumstances of rice production. The studies have shown that rainfall variability is a more important limiting factor than length of season. While no rice was grown in the infertile, acidic soils of the Andean region,

commercially viable yields are possible when these soils are found in higher rainfall areas.

How much information about ecological settings should the centers acquire? Clearly the scope is limitless for documenting in ever greater detail the minutia of ecological diversity. At some point, however, the additional knowledge will contribute less to improvements in the allocation of research efforts than it costs to acquire, signalling a stop to further efforts.

END FEATURE

Ideally, the environmental limits for the application of a research finding would be known; the environment would be represented as a multi-variable continuum over the earth's surface; and matching of the two would provide a map of the areas where the finding could be successfully applied.

The environmental limits of a research finding generally are not sharply defined, because the limited amount of testing that is feasible often includes few, if any, near-boundary cases. Also, year-to-year variability especially of rainfall, and of variables influenced by it such as soil aeration, nitrogen availability or flooding regime, may cause a gradual transition between regions suitable and unsuitable for application of a research finding.

15.5.4 Environmental data bases

A multivariable continuum of environmental information can, in principle, be modeled by a data base containing information for point locations which is then subjected to efficient two-dimensional interpolation. Data base management systems with such possibilities are under development in different places, including some of the international agricultural research centers.

Point data, such as rainfall or solar radiation, can be integrated with information on delineated areas as derived from soil or land use maps, by assigning interpolated values of the former and specified values of the latter to the cells of a map grid, over the area of interest. Such a grid data base requires a very large amount of memory if the cells are small enough to minimize information loss, but could be matched against many kinds of requirements without the constraint of class boundaries fixed beforehand.

Elements for a world-wide data base exist, e.g., in the form of the digitized soil maps of the world (in FAO), but for most purposes more detail will be needed, e.g., a 1:1 million scale equivalent. The International Soil Reference and Information Center is presently exploring ways to get such work under way. Current data sets will need to be linked into any overall data base to minimize cost and ensure optimal accessibility and use.

15.6 Centers and Environments

The system of international agricultural research centers, or the much wider system that includes the national agricultural research institutes, cannot respond specifically to all the needs of farmers in their diverse and complex environments. In Bangladesh alone, for example, about 480 distinct soils series have been recognized, many of which may occur under different flooding regimes. Even individual farmers normally use several kinds of land and manage these differently.

Therefore, agricultural research has concentrated on improving components of farming systems expected to be applicable in a wide range of conditions, as in the continuing search for new lines with high yield potential, stability and broad adaptability.

Agricultural researchers have recognized that no single "best" lines exist for all environments, and that their performance, as well as the response to management or land improvement measures, depends on the nature of the environment. This has led to several developments, briefly indicated below and systematically summarized in the previous sections.

Climate zones and soils of the world and of regions, countries or project areas have been surveyed at different scales and degrees of detail. On a world scale (FAO) and in some countries (e.g., Kenya) this information has been integrated into maps of agroecological zones.

General maps of present land use have been produced, as well as maps indicating extent or prevalence of specific crops (e.g., CIAT, IRRI). For some crops, the total area of their occurrence has been subdivided into a small number of mega-environments, requiring germplasm with contrasting qualities (e.g., CIMMYT). Within some of these mega-environments, macroregions have been identified on the basis of the presence or absence of specific stresses (e.g., CIMMYT now have such regional and descriptor data organized and mapped for 23 of 25 intended countries).

Yield data from multilocation trials with common sets of lines or clones have been used to cluster the experiment sites into groups with common patterns of relative yields. Efforts are being made to define and assemble a minimal necessary set of environmental data for each site in such experiments (e.g., ICRISAT, IRRI).

For specific stresses reported to occur over large areas, such as aluminum toxicity and phosphate deficiency, certain fungal diseases or insect pest incidence, screening of lines or populations for resistance or tolerance as well as agronomic experiments are concentrated in sites representative for the stress (e.g., CIP, IITA).

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* The site-season can be considered as the basic unit of environment. The number of environments is essentially infinite, but only part of the variation is of practical importance.

* Environment variables determining the applicability of research findings may be of many different kinds and have many aspects not under human control.

* CIAT has entered basic environmental data for several thousand sites into computer storage accessible through a geographical data-base management system to enable a more specific response to different questions about environments. Other centers (e.g., IRRI, ICARDA, ILCA) have developed similar systems.

* Matching genetic materials, management and improvement methods with environments is a continuing activity.

* Mega-environments are generally characterized in broad climate terms. Regions distinguished similarly but with some soil differences also taken into account are termed agroecological or edaphoclimatic zones. Where large regions within a mega-environment can be characterized by combinations of stresses a macroregion can be defined. A recommendation domain or a microregion is an area with a similar land type or recurrent combination of land types, and a set of common social, economic and infrastructural conditions faced by farmers.

* Universal or ideal clones or cultivars do not exist and so choices must be made in plant breeding, and cultivars or clones are designed and selected for resistance to tolerance of combinations of stresses prevalant in specific environments.

* The relative performance of lines often shows greater variation among low-yielding sites because of the many reasons for poor yields including drought, low solar radiation, nutrients, toxicities, establishment, weed competition, and incidence of diseases and pests.

* Once general levels of certain disease or pest pressures are correlated with environments, species introduction may be pre-tested for resistance against the most serious of the likely threats.

* Since climate and weather conditions determine the likelihood of damage from many pathogens and pests, a subdivision into homogenous edaphoclimatic regions makes it possible to develop specific management recommendations against them. For soil-related pathogens or pests, a further subdivision is needed to arrive at homogenous recommendation domains.

* Any complete farming system is applicable only within a fairly narrowly circumscribed environment. Farming systems researchers have spent much effort on environmental description and analysis. In the Philippines, rainfall probabilities have been used for fine tuning of the cropping patterns.

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* On-farm research, as done by several centers, is designed to identify technically, economically and socially feasible methods of intervention. If the results of the research are to be effectively spread, the areas with the same sets of site characteristics need to be delineated.

* Examples of effective identification and mapping are the probability of drought periods in the monsoon season, which separates the areas in southern India suitable for two farming systems developed by ICRISAT, or flooding depth in Cagayan valley, northern Philippines, which delimits the area of successful improvements developed by IRRI for a rice-based cropping system.

* Where low-yielding sites with different kinds of limitations are analyzed, environmental characterization provides essential information to explain performance. Mega-environments have been characterized generally in terms of temperature and rainfall regime. Further work is needed to identify rapid, effective methods of characterizing and mapping recommendation domains or homogenous crop regions at low cost and with a small proportion of the work having to be done by highly trained specialists. The environmental limits of research findings are generally not sharply defined, because few, if any, near-boundary cases can usually be tested.

* The centers and national programs cannot respond specifically to all the needs of farmers in their diverse and complex environments. In Bangladesh alone, for example, about 480 distinct soil series have been recognized, many of which may occur under different flooding regimes. The centers have concentrated on improving components of farming systems expected to be applicable in a wide range of conditions.

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* General maps of present land use have been produced, as well as maps indicating extent or prevalence of specific crops (e.g., CIAT, IRRI). For some crops, the total area has been subdivided into mega-environments, requiring germplasm with contrasting qualities (e.g., CIMMYT). Efforts are being made to define and assemble a minimum necessary set of enviromental data for each site in cluster analysis of multilocation trials (e.g., ICRISAT, IRRI. For specific stresses such as certain fungal diseases or insect pest incidence, screening of lines as well as agronomic experiments are concentrated in sites representative for the stress (e.g., CIP, IITA).

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16 FARMING SYSTEMS RESEARCH

16.1 Introduction

The need for farming systems research and its usefulness lie in the degree to which traditional research approaches of a disciplinary or commodity nature fail to produce outputs that are actually used by farmers. The greatest need and opportunity for a farming systems approach are in the development of improved technology for the masses of small-scale farmers in the developing countries. Such farmers generally have neither the education nor the information services to enable them to act as good integrators of new scientific information. They have consequently been unable to make good use of the results of traditional research. Such research has generally overemphasized biological potential and yield considerations without giving sufficient attention to other criteria relevant to resouce-poor farmers. Through closer involvement of these groups in the research processes, farming systems research promises to overcome these deficiencies.

Until the 1970s, little was heard of the farming systems approach to research. Since then it has had no shortage of either powerful proponents or opponents in national and international forums, suggesting that farming systems research is significant and revolutionary. Yet farming systems have, necesearily, existed ever since farming began and with hindsight, it could be argued that much successful agricultural research has been that which was conducted with a strong (perhaps

implicit) farming systems orientation. Nonetheless, institutional research specifically organized in terms of farming systems is relatively new, dating spasmodically from no earlier than the 1930s. Only in the past decade has farming systems research gained significant formal recognition via sanctioned budget appropriations and designated program activities within research agencies. Given this youthfulness and the complexity of the issues addressed, it is perhaps somewhat premature to be seeking to identify on-farm impacts, which seemingly lie yet in the future.

While there is still much discussion over various points of detail, the general framework of methods for farming systems research is no longer a matter of contention, as evidenced by the general consensus to be found between, for example, Collinson (1982), Dillon, Plucknett and Valleys (1978), Gilbert, Norman and Winch (1980), Norman (1980), Shaner, Philipp and Schmehl (1982) and Zandstra et al. (1981). After an introduction to the farming systems approach, an overview of the methods of farming systems research is provided, outlining the consensus position. This is followed by a discussion of some organizational matters. Then some remarks are offered about the role of the centers in farming systems research, providing a framework against which, in the penultimate section, the activities of the centers under this heading are assessed.

The centers' work on farming systems research is still young, in most cases, so that significant impact is still in the future. Substantial benefits do, however, seem to be in store including benefits associated with better soil and water conservation and use, but further patience will be required of supporters while the work matures.

16.2 The Farming Systems Perspective

What is the farming systems approach to research? Certainly it does not imply the use of some new independent science. Rather, it involves knowledge available from the physical, biological and social sciences (i.e., from the standard pool of knowledge used in traditional agricultural research) applied using a systems approach (Couger and Knapp 1974) to inquiry. Thus farming systems research is holistic in outlook and is both multi- and interdisciplinary. Reflecting a concern with understanding farmers' real systems, the activities of farming systems research include both research on farms and on experiment stations, on occasion trading less control for more relevance to an extent that is unusual in traditional research focused on a particular discipline or commodity.

Basic to farming systems research is an appreciation of the farm as a system of which the farmer and the farm household are integral parts (Dillon, Plucknett and Valleys 1978, p.8). Following Shaner, Philipp and Schmehl (1982, p.16), a farming system can be defined as a unique and reasonably stable arrangement of farming enterprises that the household manages in response to the physical, biological, and socioeconomic environments and in accordance with the household's goals, preferences

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and resources. Every farming system is part of larger systems - e.g., the local community - and can be divided into subsystems - e.g., cropping systems. Thus it involves complex interaction between a variety of interdependent components, including human and technical elements. The technical elements, specified in terms of available technology and climatic and resource constraints, define production possibilities. The human elements involve endogenous and exogenous factors (including the socioeconomic and cultural environment) that influence farmers' decisions about the operation of the farming system and choice of technology.

16.3 The Methods of Farming Systems Research

A synthesis of farming systems research methods is presented in Figure 16.1. Broadly, nine activities are involved. To a degree, particularly in the initial stages, these activities will be sequential. However, once an ongoing program is established, it is likely that several the activities will be going on simultaneously.

A target domain is selected having regard to the development goals and priorities in the country or region of focus and to the mandate of the research institution. The target domain should be chosen to give a fair chance of obtaining tangible results in reasonable time and be broad enough to spread costs (Perrin et al. 1976). The most satisfactory delineation is likely to be based on relative homogeneity of the farming system currently used or of a system's edaphoclimatic environment.

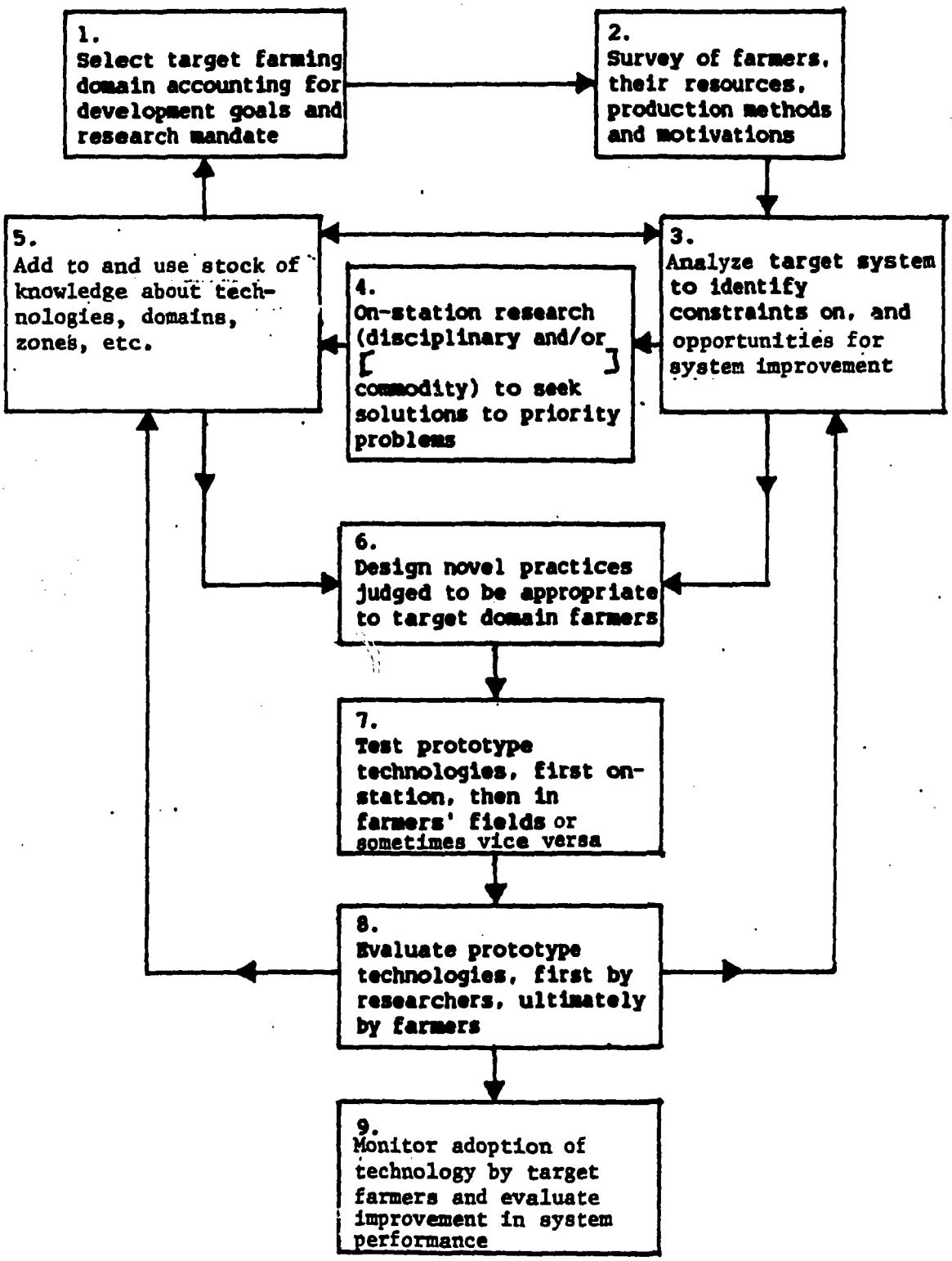

Figure 16.1 A schematic generalization of farming systems research.

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As a basis for the further steps in the research process it is necessary to investigate the existing farming systems in the target domain to identify farmers' production methods, resource availabilities, priorities and decision criteria. Several alternative methods have been developed at CGIAR and other centers for such investigations. These include both reconnaissance or exploratory surveys and formal surveys (Byerlee and Collinson 1980, Byerlee, Harrington and Winkelmann 1982, Gilbert, Norman and Winch 1980. Chambers and Ghildyal 1984 and the 1981 special issue of Agricultural Administration on rapid rural appraisal). The former are relatively quick and cheap. They typically involve a week or so of field travel through the target area by a small multidisciplinary team (e.g., an agronomist and an economist) which meets with representatives of policy-making and farmer-contact agencies, community leaders and, above all, farmers and their families. The disadvantages are that the types of information that can be collected are limited and some data may be subject to substantial bias. Reconnaissance surveys are most useful in refining the definition of the target domain and in identifying priority issues for further research.

Formal surveys, in contrast, typically involve some considered form of sampling, designed questionnaires and an orientation to conventional statistical standards of accuracy. They vary in ease and speed of implementation and scope of coverage but, typically, profiles of labor availability, cash flow, work demands, prices received, etc. can be built up in this way and, if the collections run sufficiently long, the variability over time, especially in response to natural hazards like

flood, drought and fire, can also be quantified. In contrast to informal exploratory surveys (e.g., as implemented by the CIMMYT Economics Program), formal surveys are likely to be time consuming and costly. This will be particularly so if the formal survey is of a multi-visit panel nature as is usually necessary for accurate recording of ongoing activities of production processes, household transactions, time allocation, etc. such as used in ICRISAT's Village-Level Studies in India and ICARDA's Farming Systems Village Studies in Syria.

If time and resources permit, and the need is seen, both exploratory and follow-up formal surveys will be conducted. In terms of gaining an understanding of existing systems and opportunities for change, they are complementary and best seen as relating to different stages in a program of farming systems research. The rough and ready information of an exploratory survey may sometimes suffice. If systems modeling (e.g., mathematical programming analysis) is used, more detailed information obtainable only via formal survey procedures may be needed.

The primary purpose of the survey information is to gain an understanding of the constraints faced by farmers in the target domain and the opportunities open to them. The constraints may be those imposed by limited resources, including limiting edaphic factors or biological materials. Opportunities may be identified in terms of underutilized resources, such as labor surpluses or land lying fallow during certain seasons, or in terms of potential scope to break important constraints. The analysis of opportunities will be aided by

drawing on the stock of knowledge about production processes and technologies, perhaps using experience of improving broadly similar systems in other places.

From appraisal of the constraints and opportunities and from the pool of existing knowledge (including results of relevant research), judgments can be made as to system changes that might be appropriate. This creative design activity should generate a few sets of improved practices for possible development and testing on the experiment station and at farm level.

Also arising out of the analysis of constraints and opportunities, a variety of problems (e.g., diseases, marketing difficulties, etc.) will be identified needing further research. The feasibility, potential benefits and priority of addressing these problems need to be established before undertaking research aimed at their solution. Having decided on the portfolio of problems to be researched in greater depth, commodity or disciplinary research on the relevant system components can be conducted on the experiment station or, in some cases, immediately on farms. This research may be oriented to single or multiple components and may involve quite basic research, albeit guided and constrained by an ultimate focus on improving the target farming system by adding to the stock of relevant knowledge. As the stock of knowledge about the target farming system grows, it allows more perceptive analysis of the constraints on, and opportunities for, system improvement.

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The crucial stage of farming systems research is the development and testing of possible system changes via experiment station trials and on-farm testing. Generally, the greater the stock of existing knowledge pertinent to the system under study, the shorter will be the time required for this stage. Prototype technologies are usually tested first on the experiment station before being tested in farmers' fields. Sometimes, however, on-farm work can be a valuable anticedent to work on experiment stations.

Farm-level evaluation via both researcher-managed and farmer-managed trials is a crucial element of farming systems research. Performance of potentially improved technology will usually drop as it is moved from the artificial conditions of the experiment station to farms, particularly when tested under farmer management for compatibility with the existing system. Needless to say, the experimental designs and procedures used in on-farm work are usually much simpler than those used on-station.

Researcher-managed farm trials can cover more treatments than farmer-managed trials and should be aimed at screening proposed technologies from the design or experiment-station stage, at fine-tuning them to local conditions, and at evaluating their potential for local and regional coverage. All this is, of course, easier said than done and will take several years. Figure 16.2 indicates the time scale expected to apply, for example, in ICRISAT's Work in developing improved land and water management systems.

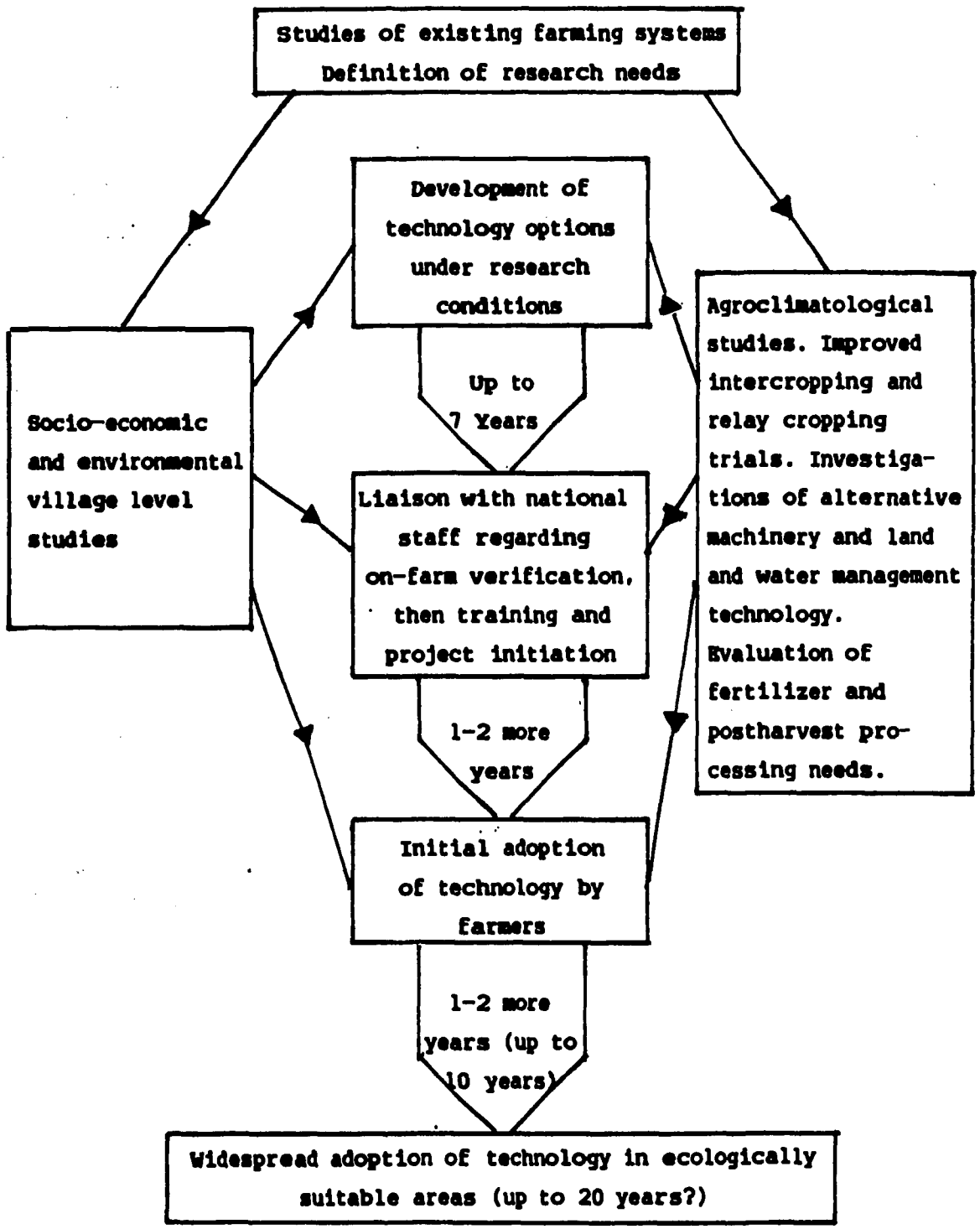

Figure 16.2 Steps in ICRISAT's development of improved farming systems

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The process of prototype technology design and testing must involve on-going economic assessment, initially in an ex ante context to cull less promising suggestions, and later in an ex post context based on trials in farmers' fields. Economic assessment of prototype technologies, as practised variously at CIAT and ICRISAT, for example, is discussed by Anderson and Hardaker (1979), Banta (1982), Ghodake and Hardaker (1981) (Figure 16.3) and Ryan, Sarin and Pereira (1979). The analyses should obviously be based on performance with farmers' management, predicted if not observed, and ideally using choice criteria of the farmers, as identified in the survey phase. Because of the difficulties in identifying and quantifying these criteria, the ultimate test must be the willingness of farmers to adopt the technology.

An important distinguishing feature of farming systems research is the feedback, depicted in Figure 16.1, from the assessment of the prototype technologies on station and, more relevantly, on farms, to the stock of knowledge about the target farming systems themselves and the new technologies that might be introduced to those systems and to the analysis of the constraints and opportunities of the target group. It is this feedback that leads to progressive, constructive redesign of improved practices until they are well adapted to the needs and circumstances of the target group of farmers.

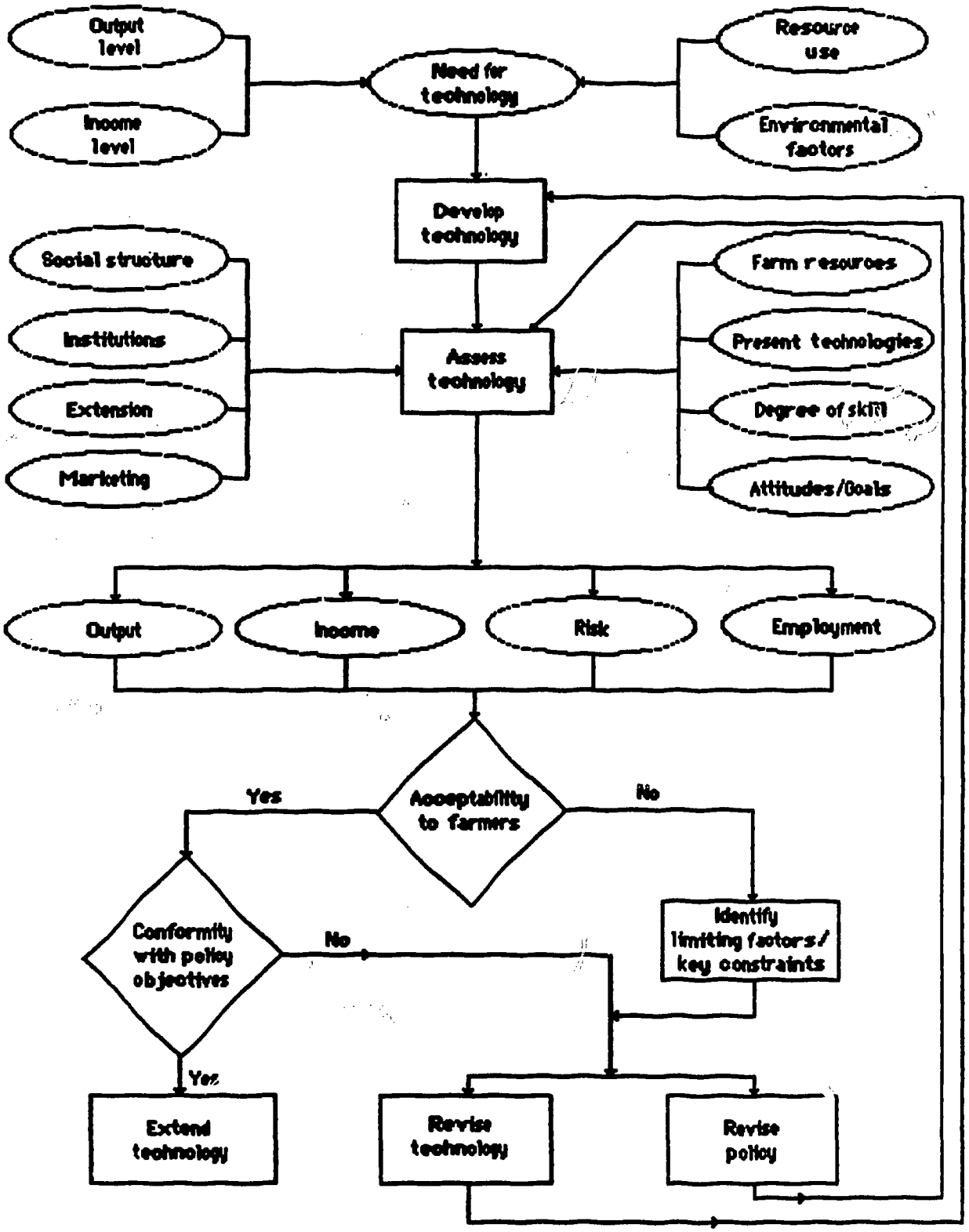

Figure 16.3 Technology assessment in a farming systems research context.

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FEATURE: Farming Systems Research and Groups

Much of the discussion about farming systems research is principally directed toward the needs of individual farmers. However, there are important types of technologies that require group action by farmers to have an impact on agricultural production. Examples include watershed planning and livestock disease management. Thus far, farming systems research on group technologies has been limited. ICRISAT's Vertisol technology research in India and ILCA's introduction to Ethiopia of oxen-drawn excavators for small-scale water harvesting are two examples of center involvement in group technologies.

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Extension workers should be involved directly in the on-farm testing activities so as to be fully informed about the work. They, along with other members of the farming system research team, should monitor the spread and evaluate the performance of any newly introduced technology so as to provide feedback on any relevant issues to research managers, sponsors, if any, and policy makers. Monitoring and evaluation account for the various perspectives of farmers, researchers and society as a whole.

16.4 Issues in the Implementation of Farming Systems Research

16.4.1 Organizational challenges of farming systems research

Compared with a traditional organization of research on the basis of disciplines and/or commodities, farming systems research has strong implications for the organization and management of research. By virtue of its holistic approach to the problems of agricultural production, farming systems research is multidisciplinary in nature. Consequently, it should be organized so as to provide a means by which multidisciplinary teams of researchers can examine relevant problems of the target farming systems, including problems relating to relationships between system components that may transcend conventional disciplinary research boundaries. The organization of farming systems research should thus be such as to encourage effective interdisciplinary interaction. Such interaction is best encouraged by purposive leadership and voluntary cooperation rather than solely by formal institutionalization through structural changes to research bureaucracies. Procedures and mechanisms have to be developed that facilitate joint work without stunting individual initiative and effort.

The successful operation of farming systems research places great demand upon the researchers involved. Coordination must be frequent and be undertaken by the people directly concerned. Teamwork is essential. Most importantly, the intra-institute organizational structure for the work must be flexible. As the research task changes, so too, if need be, should the team orientation, its membership and its leadership. Good leadership is essential and is unlikely to be achieved if the choice of leaders is determined mainly by seniority. A high standard of professionalism is required of all team members which, in turn, requires that personal professional goals must be realizable within the system and the team.

The farming systems research approach requires that the research workers should be involved in all steps of the work. One group does not stop at one stage and hand over its results to someone else for further development and testing. Rather, the same team should participate in all stages of the problem-oriented research, and especially in the work in farmers' fields. Research with a conventional approach is usually much more compartmentalized across time and space.

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FEATURE: Integrating Social Scientists into Farming Systems Research

In the post-euphoric phase of the industrial and green revolutions,the importance of human, social and economic factors in farming systems is so widely recognized that it requires little further elaboration here. Research administrators, whether they be in regional, national or international organizations, are generally responding by ensuring that social scientists are represented, at least to some degree, in research structures.

The form of their representation varies widely, reflecting such things as the prejudices of the administrators and their influential scientific (especially from other than the social sciences) advisers and the availability of social scientists with backgrounds and interests in agriculture. The range extends from a token and peripheral appointment or two, though specialized service divisions of social sciences, to complete integration of social scientists in multidisciplinary research and problem-solving teams. In spite of the diversity, the institutional incorporation of social scientists generally appears to become morehaphazard the more local is the level of organization. Thus, for example, social scientists are pervasively involved in the centers but, at the other extreme, can be almost non-existent at the regional agricultural research stations of developing countries where priorities have usually been given to activation of biological research. Perhaps it is the political sensitivity of socio-economic research findings (e.g., on income

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distribution issues) that has slowed the advancement of social sciences in much agricultural research, manifested, in the past, in failures to train adequate numbers of people for such posts. Fortunately, however, the situation is improving in most countries (but still not all).

What is it that social scientists have to offer in farming systems research? One important set of activities is the assembly of information on such matters as (a) the social milieu in which farm decisions are made, (b) the institutional setting and policy environment in which farming is conducted, including land reform, credit and taxation, (c) the economic environment of farms, including long-term market prospects for inputs and outputs and, most importantly, understanding of the opportunity costs and transaction costs faced by farmers, and (d) the attitudes and personal constraints of farmers, including their desire or otherwise for change, for leisure, for education, for different foods and so on, and their human and other capital. The purpose in such work is to assist in the identification of effective changes to and designs of practices, techniques, enterprises, activities and policies that are acceptable to and appreciated by the target groups in farming systems research. The days of the 'quick' technological 'fix' have just about gone and progress now must be won through better understanding of the full reality of farming systems.

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FEATURE: Addressing the Needs of Women in Agriculture Through Farming Systems Research

Existing farming systems research, like so much other agricultural research, may well be biased against the interests of women in agriculture and, hence, may fail to perceive the true potential productivity of farming systems or unfairly redistribute costs and benefits through its inventions.

Potential bias arises first from the idea that agriculture is the primary variable affecting the livelihood of resource-poor farm families. Yet where male and female economic activities are gender-determined and where women concentrate on non-agricultural activities, the focus of farming systems research on farming techniques may mean that opportunities to improve the productivity of other work, done by women, may be overlooked. Yet the scope for raising family living standards by just such improvements may be as great as in farming methods.

Second, farming systems research has inherited from conventional research the notion that attention should be directed to improving foodcrop production. But a crop becomes food only after it has been cleaned, preserved and stored, prepared and, in most cases, cooked. The returns to improvements in these activities, commonly undertaken by women, could possibly exceed returns from efforts directed to improving crop yields.

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Third, partly because of mandates of the centers, and partly because of the need to focus available research resources on crops and animal types that loom large in commodity trade or in real farming systems, little attention is directed to minor crops and small animals. Yet, once again, these are often the particular responsibility of women, whose contribution to family welfare might be appreciably increased by the diversion of some research resources to these production areas. Indeed, because of the ways farming systems are perceived by (mainly male) researchers, the activities within the system that are controlled by women may be underestimated and undervalued.

Fourth, the large and in some areas growing numbers of farming households headed by women, as well as the own-account production of wives, especially second and beyond wives in polygamous marriages, has tended to be subsumed within concepts of male-managed household enterprises as the typical units of production.

The undervaluation of the contribution of women arises also because farming systems researchers have generally failed to integrate the management of household maintenance and reproduction into their analysis of system performance. Fetching water to irrigate a vegetable crop is seen as part of the farming system, but fetching water for cooking - probably a more essential task for the survival and reproduction of the household - may too often be omitted from the analysis of labour time use.

Farming systems research practitioners acknowledge the need to identify the goals and objectives of farmers in the target domain. Usually this means that the priorities of the male head of the farm household are investigated. Seldom is it recognized that a woman's objectives, partly because of their roles in domestic crop processing and feeding the family, partly because of the alternative claims on their labor time, and partly because of their tasks and management responsibilities in their own food crop production, are likely to differ from, and may conflict with, those of the man. The risk of bias in farming systems research arising from the failure to recognize such differences, not to mention the failure to try to account for them, is serious.

To some extent, of course, the focus on the interests of men in farming systems research reflects the inferior status of women in many situations and their relative powerlessness to make independent decisions, including decisions about the technologies that affect their work and lives. A full-blown program for farming system improvement would consider the institutional and infrastructural environment within which production and household maintenance takes place and would identify avenues for system improvement that could well include such things as changes in the legal status of women or raising women's participation in various types of employment. However, while the matter is contentious, the practice of farming systems research at the centers has generally excluded this broader and politically more sensitive view of the systems research agenda.

The extent to which the practice of farming systems research raises women's contribution to development depends on the sensitivity of the researchers to women's roles and perceptions. Given the paucity of data on women in agriculture and the heavy male dominance in staffing of research teams, the immediate outlook is not good. That these problems exist and are important is now beginning to be recognized. A first step towards improvement would seem to be to include more women among farming systems research staff, and to increase the training opportunities for women at the centers and in center-related training programs.

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16.4.2 Other difficulties of implementation

First, it must be recognized that farming systems research is, to a greater or lesser degree, locational specific (Menz and Knipscheer 1981). The more complex the system under study, the more locational specific it is likely to be. Hence, perhaps the greatest single problem in farming systems research in developing countries, and, indeed, for any alternative model of agricultural research, is the diversity of farming systems.

An issue for ressarchers to grapple with is the allocation of their scarce investigatory resources among so many competing systems of diverse importance, especially when importance is judged by such things as the contribution to economic growth and welfare needs of more or less neglected groups. There is no easy solution to this difficulty but, minimally, research decision makers must be sensitive to the tendency to concentrate resources on farm people already favored relative to those in less accessible areas. The price of social relevance may be that work that is more difficult and less scientifically satisfying must take precedence over opportunities that are easier and more comfortable. Special funding may be required in many instances and, with the growing recognition of farming systems research among donors, it is to be hoped that this may be increasingly obtainable.

16.5 The Centers' Roles in Farming Systems Research

Almost everywhere it is undertaken, farming system work tends to provoke controversy, in part because of widely held scepticism among many research

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practitioners of more traditional ilk and in part because of diverse practices conducted under this rubric. Although there is reason to believe that consensus is emerging, some controversy remains about the propriety of centers' involvement in farming systems research, and the purpose and work programs in this field at those centers where such programs exist.

Farming systems research seems clearly most suited to the circumstances of national agricultural research programs, since it is specific to the relatively small numbers of farmers in selected locations that form the chosen recommendation domains. With target domains of typical size and scope, the numbers of domains to be studied worldwide make the task clearly several orders of magnitude beyond the present and potential resources of the centers. The mandates of the centers are too broad for them to make a major commitment to farming systems research directed to just the few target groups that they could realistically cope with. Rather, it can be argued, the centers should be concentrating on expanding the stock of knowledge about the production technologies on which effective farming systems research by national programs heavily depends.

Yet these arguments are incomplete in two main respects. First, the task of expanding the stock of knowledge for national farming systems research programs imposes on the centers a need for relevance in their basic research and prospective technology development activities. Such relevance can best be assured through the feedback mechanisms of farming systems research. Second, the capacities of national programs to conduct effective farming systems

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research often need reinforcing. It is to be expected that national agricultural research agencies, facing, as they often do, personnel and other resource constraints, will look to the centers for guidance and help in their farming systems research. These arguments indicate the desirability of the centers engaging in farming systems research work, but in ways which are symbiotic with national programs.

According to this view, the centers' activities in farming systems research should be directed to the development of research methods and to the more direct support of national programs - for example, by providing technical assistance and training, by supplying prospective technologies for on-farm testing and by sponsoring collaborative activities such as farming systems research networks.

To summarize, and following Sands (1985), a farming systems research program at a center should have the following responsibilities and activities:

(a) develop and refine farming systems research methods for transfer to national programs;

(b) organize training programs in farming systems research for research workers in national programs;

(c) directly manage a limited farming systems research project, partly as an end in itself and partly as a vehicle for (a) and (b) above;

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(d) provide technical support and, where appropriate, organizational guidance, to national farming systems research programs;

(e) develop and coordinate research networks which exploit the comparative advantages in farming systems research of the center itself and the national programs;

(f) channel feedback from farmers and national programs to center research planning and program evaluation.

Many of these activities are already being carried out at several of the centers. Nevertheless, the degree of commitment to the farming systems research ideas varies from center to center. Some assessments are made in the following section of the extent to which the centers are fulfilling the roles enumerated above.

FEATURE: Farming Systems Research in Panama

Agricultural research in Panama had traditionally been conducted by several organizations including the Ministry for Agricultural Development, the University of Panama and other public and private agencies. It was conducted on experiment stations under conditions that differed considerably from farmers' circumstances. The Panamanian Institute for Agricultural Research (IDIAP) was formed in 1975 with a view to creating a more productive research system.

The new agency was to focus directly on research for specific crops and regions. It aimed at developing technologies to relieve the constraints to production on representative farms. Research was focused on the most critical problems facing farmers, in the crops and areas given highest national priority.

A pilot project was set up with CIMMYT in the area of Caisan, a zone of 10,000 ha with 3,000 families. The immediate aim of the project was to raise incomes and productivity in the maize and bean cropping system; the longer term aim was to gain experience in conducting on-farm research and linking it with the agricultural research system. Through workshops, training courses and learning-by-doing, the Caisan pilot scheme was to serve as a means of incorporating on-farm research procedures into IDIAP's institutional structure. In short, the project sought to accomplish both technical and institutional innovations. CIMMYT contributed the methods for on-farm research and training; IDIAP provided the research resources (staff, housing, vehicles, supplies).

Several technological changes were identified, tested and promoted through the on-farm research work. All these related to agronomic practices including, weed control, spacing and density, tillage and fertilizer use. The pattern of adoption of new practices was carefully monitored.

To evaluate the returns to this strategy requires an answer to the question of what would have happened in the absence of the on-farm research program? There are two aspects to the answer. The first is whether the traditional approaches would have identified the same research problems and hence eventually have generated the same new knowledge. The second is whether the existing institutional arrangements would have resulted in a similar rate of adoption.

A conservative judgment was taken that the innovations would have been the same under the traditional research system. However, the adoption rates would have been lower in the early years of the project. In other words, the benefits were those arising from a more rapid diffusion of new knowledge resulting from the manner in which it was generated, tested and diffused. When this assumption was invoked, the investment in the work was estimated to generate an annual flow of net social benefits of between $1.9 and $2.5 per $1 invested by Panama. Neither direct CIMMYT costs nor benefits to other countries through CIMMYT's international programs were considered in these calculations.

The progress of the project and the experiences with the method were followed closely by the research directors. The method involved on-farm surveys and experiments, the use of an informal survey leading to a focused

questionnaire, the pre-screening of best-bet technological components and the management of experimental and non-experimental variables for on-farm testing. Each step was carefully documented in order to ensure its transferability to other projects. In 1978, two national staff from IDIAP were assigned to the Caisan project. By 1983, 45 research staff were involved in eight priority areas of crop and livestock research for specific zones, all built around the on-farm research methods first tested in Caisan.

Projects such as these can constitute a most worthwhile investment by the centers. In general, if well conceived and executed, the return to the collaborating country should be high: but this is to be expected given the resources provided by the center. A more global evaluation demands that the full costs of those resources be included. Simultaneously, of course, the benefits in other projects, regions, and countries must be counted. This is the essential element in the case for justifying center involvement in specific on-farm research projects. There are two types of benefits. One arises from the wider use by the national program in the particular country of the methods and approaches which were tested and modified to local circumstances in the pilot study. This appears to have been the case in Panama. The other stems from the economies of size that the centers can exploit. Developing new approaches and methods may not be a justifiable investment for a nationalprogram, especially in a small country. However, the center may well be able to spread its development costs over 10 or 15 countries.

In summary, the success of such ventures appears to hinge on the following questions:

(a) Are the methods and approaches sufficiently flexible to adjust to local circumstances?

(b) Will the project provide an opportunity for national program staff (beyond the project staff themselves) to gain experience with the approach?

(c) Will this lead to a wider adoption within the country?

(d) Can the international center use this case in other countries? Positive responses to all of these, although not ensuring success, would help justify case study involvement in on-farm research by international centers. In contrast, in the absence of generalizable lessons and transferable results, specific on-site involvement is likely to be a costly venture with few if any gains above those from the site-specific, traditional experiment station approach, which on-farm research is intended to replace.

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16.6 An Assessment of the Activities of the Centers in Farming Systems Research

Consistent with the declared objectives of farming systems research, the activities of the centers under this rubric can only properly be judged by the extent to which farmers in the recommendation domains are assisted to achieve better their objectives (Anderson 1985). However, given the roles of the centers in this work, the farm-level impact will normally be achieved indirectly, through national agricultural research programs, making direct assessment of the impact difficult. It seems more appropriate, therefore, to attempt an assessment of the centers' contributions relative to the specific responsibilities and activities listed at the end of the previous section.

Development of methods. An important lead in developing farming ystems research methods was taken by the Economics Program at CIMMYT. In collaboration with national programs, CIMMYT has developed and refined its methods for farming systems research through more than a decade of field experience. These methods are usually described as on-farm research with a farming systems perspective.

In various ways, other centers, including CIAT, CIP, ICRISAT, IITA and IRRI, have also contributed to the extant methods. While there are many similarities in approach between the centers, there are also some differences, such as the pastoral orientation of ILCA's work and the soil and water conservation emphasis at ICRISAT. In developing and testing methods, such differences are healthy since, through evaluation of alternative approaches, the best methods to suit

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particular circumstances can be identified. A problem may arise, however, when such differences are carried over into training programs and where two or more centers are cooperating with a particular national program. This has been a problem in the past but the better coordination needed among centers in their training and collaborative work is beginning to be implemented.

Training programs. In Zimbabwe, the establishment of a farming systems research unit in the Department of Research and Specialist Services in 1982 can be traced to a demonstration of its farming systems research approach provided by CIMMYT for research staff in 1980. The exercise, which was a study of an area of small-scale farming, was one of the first evaluations of its type in peasant farming in Zimbabwe. The amount of useful data generated, coupled with the rapidity and low cost of the approach, impressed those involved and set the stage for the uptake of the farming systems approach in the country.

Other centers that have been active in promoting the farming systems research approach in tropical Africa are ILCA, IITA and ICRISAT. In fact, much of the growing interest in farming systems research in Sub-Saharan Africa (though not all of it) can be traced to the influence of the centers.

CIMMYT has been active in providing farming systems research training (to nearly 500 participants in E. and S. Africa) that has been appreciated by a number of national programs. For example, the establishment in Malawi of adaptive research, using a farming systems research approach, has much to do with the ready access by the national program to training courses from CIMMYT's

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regional program as well as the in-country program of CIMMYT. There are three types of training offered and these are designed to be complementary: orientation sessions of three to ten days; regional training workshops of five weeks a year; and in-country training program "calls" over 15-18 months. The material covered in the calls matches critical stages in the farming system cycle and evolves to match the growing experience of the participants.

Globally, much yet remains to be done in familiarizing research workers with the concept and in offering hands-on experience. Ideally, university curricula in agricultural science should inculcate appropriate methods and practice but there is far to go in this respect in all countries.

Conduct of farming systems research projects. At a number of centers, farming systems research programs that might be thought of as demonstrations have been created, wherein the center is organized to feature a multidisciplinary farming systems program, set up primarily or partly to show the way forward (as well, often, as to provide a model for farming systems research training). The programs at IITA, ICRISAT and perhaps ICARDA exemplify this type of work even if the interdisciplinary collaboration has not always been exemplary. As a direct demonstration vehicle, such models encounter some 'buyer resistance' through appearing to potential 'customers' as demanding financial resources beyond the reach of national programs. They do, however, also offer the opportunity for a center to demonstrate that commodity-oriented research thrusts need not be confined to "mandate" crops; ICRISAT's farming systems program, for example, has worked on 11 crops beyond the five in the center's mandate.

There are numerous benefits for a center from maintaining a farming systems research program over which it has full control. Most importantly, it can bring center research workers into direct contact with some of the small-scale farmers who represent the ultimate consumers of their research output. Second, through hands-on experience, the center can better fulfill several of the activities and responsibilities noted above, such as development of farming systems research methods and provision of training. A center-run farming systems research program also serves to channel feedback to the center's research allocation decisions. In these respects, a good example of a center-run project is the Mantaro Valley Project of CIP in Peru in which the "farmer-back-to farmer" method for generation and transfer of technology was developed.

Direct support of national programs. CIMMYT's work in E. Africa and ICRISAT's work in W. Africa are notable examples of provision of support for national farming systems research programs. The concept is to share hands-on experience with national investigators and research planners to extend the approach as a model for organization and management of research. The pilot farming systems research project in Panama set up by the Panamanian Institute for Agricultural Research with collaboration and support from CIMMYT (see Feature) is another example of the same philosophy of a center's involvement.

Coordination of research networks. In the development and coordination of research networks, the experience of the Asian rice-based cropping systems research network, supported by IRRI, is encouraging. Recognizing land scarcity as the principal constraint to expanded rice production in S. and S.E. Asia, the

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Cropping Systems program at IRRI has been focused on increasing cropping intensity through the development of short-duration rice varieties coupled with farming techniques that permit double cropping with rice or with rice and a secondary crop. National agricultural research programs within the network fine-tune the prospective technologies designed by IRRI to the specific circumstances of farmers in selected recommendation domains. At the same time, feedback from these national programs is used in setting priorities for component research at IRRI.

The major networking activity across the spectrum of different countries and diverse activities of centers and national programs is the Farming Systems Support Project and related projects of USAID. The centers' activities in networking in this field are usually more limited and naturally usually reflect mandate orientations (an exception is the Farming Systems Newsletter of the CIMMYT East Africa Economics Programme).

Such support activities of the centers might, through diffusion among agencies in developing countries, in time, enable the challenges of large numbers of recommendation domains to be appropriately met. However, CIMMYT, ISNAR and others (e.g., Biggs and Heinemann 1985) have stressed the need for a flexible and pragmatic approach to the development of farming systems research capacity in national programs. Installing farming systems research in an institution organized along commodity or disciplinary lines, and with limited professional and other resources, presents obvious difficulties, perhaps requiring modification of the 'model' approaches developed at the centers.

Feedback to centers' research management. As noted above, centers directly engaging in farming systems research projects can channel information arising from these projects about needed further research into the research policy making process at the center. Component research priorities and programs can be influenced by farming systems research in representative domains where the mandate crops are grown. Such use of farming systems research has been highlighted at various times by the programs at CIAT, ICRISAT and ILCA, for example. Similar feedback is possible, if more tenuous, when centers organize their participation in farming systems research through national programs.

Overall assessment. Advocates of farming systems research are firm in their conviction that the approach works and works well. They point, for example, to more than ten years of work in E. Africa and to the substantial progress made there in countries such as Zambia, Malawi, Swaziland, Zimbabwe, Kenya and Sudan (the summary in Table 16.1 reflects these and other external influences). Yet there are still sceptics and agnostics who point to the diversity, even confusion, of the farming systems research activities at the centers and to the difficulties in effectively extending the approach to national programs. They note that such national programs are much less well endowed with resources than the centers, and are often organized in ways that are at variance with the farming systems approach. Some sceptics see farming systems research as bad science that diverts research resources from more important and potentially more useful fields of enquiry. The agnostics, on the other hand, argue that the main task lies ahead and that it is too early to judge whether the intuitively

Table 16.1

Status of Farming Systems Research in E. and S. Africa

Country	Level of farming systems research activity	Institutionalization of farming systems research	Training programs in farming systems research
Angola	Nil	No	No
Botswana	4 projects	In Process	Collaborative
Burundi	1 project	No	No
Ethiopia	4 teams	Yes	Yes[a]
Kenya	8 teams	Yes	Yes[b]
Lesotho	1 project	No	No
Malawi	3 teams	Yes	Yes[b]
Mozambique	Limited	No	No
Rwanda	2 projects	In process	Yes[b]
Somalia	1 project	No	No
Sudan	3 projects	In process	Yes[b]
Swaziland	1 project	In process	Yes[b]
Tanzania	4 teams	In process	Yes[b]
Uganda	Limited	No	No
Zambia	7 teams	Yes	Yes[b]
Zimbabwe	1 unit	Yes	Yes[b]

[a] With help from CIMMYT and ILCA.

[b] With guidance and help from CIMMYT.

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appealing ideas of farming systems research can beimplemented on a near global scale. Certainly, the majority of the benefits from the approach, as it is more widely understood and adopted, lie in the future, making a comprehensive assessment at this time difficult.

The balance of the argument seems to lie increasingly in favor of the farming systems research approach. It appears that, despite a few false leads, the centers have done a good job (with help from others) in developing methods of improving farming systems that work and are reasonably "transportable" to a range of countries and institutional settings. No doubt difficulties of implementation remain (as evidenced, indeed, at some of the centers themselves), and further adaptation and improvement of the approach will be needed. But the main challenge facing the centers now is not with methodology but with extending the approach to the great diversity of countries, environments, farming systems, and research institutions, and thus eventually to bring the benefits of the approach to the needy billions of citizens of rural societies of the late developing world.

16.7 Coda

* It is inconceivable that agricultural research can ever have been conducted without some appreciation of the farming system context to which it is related. However, only in the past decade has farming systems research gained significant formal recognition via sanctioned budget appropriations and designated program activities within research agencies.

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* Being so new in its modern formal incarnation, its concepts, terms and methods are young and evolving. However, the general framework of methods for farming systems research is no longer a matter of contention. Farming systems research is holistic in outlook and is interdisciplinary in implementation. It involves an appreciation of the farm as a system of which the farmer and the farm household are integral parts.

* Refinement of the operational details for successful practice remains the key challenge in farming systems research, even though much has been learned in the centers and elsewhere. Even more urgently, given the thus far limited measurable farm-level impacts of the activities, is the need for research workers in this field to demonstrate substantive on-farm achievements.

* The greatest need and opportunity for a farming systems approach are in the development of improved technology for the masses of small-scale farmers in the developing countries. A feature of the approach is the opportunity (imperative opportunity some would say) of systematically learning from the farmers themselves and in this way assisting them to self-determine their own advancement.

* Like almost every aspect of their programs of research work, farming systems research activities at the centers are diverse in style, purpose and even the language in which they are described.

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* Farming systems research has strong implications for the organization and management of research. Procedures and mechanisms have to be developed that facilitate joint work without stunting individual initiative and effort.

* Farming systems research is, to a greater or lesser degree, specific to locations. Constraints defining locational specificity are physical, biological, economic and social. Research decision makers must be sensitive to the tendency to concentrate resources on farm people already favored relative to those in less accessible areas.

* The focus of farming systems research on farming techniques may mean that opportunities to improve the productivity of other work, done by women, may be overlooked. A crop becomes food only after it has been cleaned, prepared and, in most cases, cooked. The returns to improvements in these activities, commonly undertaken by women, might exceed returns from efforts directed to improving crop yields. Relatively little attention is directed to minor crops and small animals but these are often the particular responsibility of women.

* For a number of reasons, farming systems research in its methods and practices may have given insufficient attention to women's roles in agriculture and within family livelihood systems. The inclusion of more women among farming systems research staff and the provision of a greater number of training opportunities for women professionals would be helpful in remedying the situation.

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* While farming systems research seems clearly suited to the mandates of national agricultural research programs, the capacities of national programs to conduct effective farming systems research often need reinforcing. National agricultural research agencies look to the centers for guidance and help in their farming systems research. The youth of most of their activities means that little farm-level impact can yet be observed.

* The centers' activities in farming systems research should be directed to the refinement of research methods and to the more direct support of national programs, for example by providing technical assistance, training, prospective technologies, and farming systems research networks. Many of these activities are already being carried out at the centers. Much of the growing interest in farming systems research in Sub-Saharan Africa can be traced to the influence of the centers.

* The centers have developed and refined methods for farming systems research through field experience. While there are many similarities in approach between the centers, there are also some differences. Continuing coordination among centers in their training work is needed.

* Demonstration farming systems research programs that can be construed as demonstrations have been created at several centers, wherein the center is organized to work through and feature a multidisciplinary farming systems program, set up partly to show the way forward.

* The centers provide several examples of provision of support for national farming systems research programs. Such support activities of the centers might enable the challenges of large numbers of recommendation domains to be appropriately met. The experience of the Asian rice-based cropping systems research network, supported by IRRI, is encouraging in fostering systems thinking among collaborators.

* A farming systems research program at a center can bring center research workers into direct contact with some of the client small-scale farmers. A center-run farming systems research program also serves to channel feedback to the center's research allocation decisions.

* Although full consensus has yet to be achieved, it seems that the farming systems research approach does provide a means of tackling in an effective way some of the problems of the needy people in the late developing countries. The outstanding challenge for the centers is to extend the approach to the great diversity of farming systems around the world through national agricultural research services that exist or remain to be created to serve these people.

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17 AGRICULTURAL MECHANIZATION

17.1 Introduction

Although every effort has been made here to report on the full scope of the agricultural engineering and mechanization activities at the centers, there is a risk that some may have been overlooked, and there are undoubtedly some mechanization projects at centers not visited in this part of the study. Furthermore, manufacturers who have taken up or copied designs may not have informed the centers of their involvement. The impact of the agricultural engineers of the system is, therefore, almost certainly under-reported here and in general.

This chapter has been prepared on the basis of information assembled by staff of Overseas Division of the National Institute of Agricultural Engineering (NIAE), Silsoe, U.K., coordinated by Robert Bell. A more complete report of the work is to be published by NIAE.

17.2 Organization of Agricultural Engineering and the Centers

At most centers having agricultural engineering activity, such research has been within the farming system programs (see chapter 16) and is generally intended to reduce erosion, conserve soil moisture and reduce energy inputs. Equipment has been introduced or developed to overcome constraints to production.

Most equipment development in industrial countries has been by the private sector. In many developing countries protection of designs by patent

is not effective, manufacturing capacity is limited, and the small-scale farming sector does not offer an attractive market. There may, therefore, be a case for government or external intervention in farm machinery development on "infant or orphan industry" grounds.

A role of testing, validation and adaptation of engineering concepts and innovations, especially in collaboration with national institutes, seems readily justifiable. A role of invention and development of new machinery is more equivocal, and must balance needs for optimal use of resources and for production to be financially attractive to the farmer, against the problems of labor substitution and displacement discussed in chapter 8. The future of agricultural engineering work in the centers is thus an issue requiring on-going review and consideration by the Consultative Group and its TAC.

Mechanical innovations of value in farming have often been developed by innovative farmers and blacksmiths, especially those with well-equipped workshops in what are now the industrial countries. The tradition will surely be continued in the developing world in informal advances in technological progress. While these are important they have not been able to be documented in the following which is confined essentially to the work of the centers and some of their partner institutions.

The emphasis of recent and current agricultural engineering at IRRI, IITA, ICRISAT, ICARDA, WARDA, CIMMYT, ILCA and CIAT is sketched below. Engineering is clearly not part of the mandates of four centers and, apart from work on storage and processing of potatoes, CIP has eschewed engineering activities and, accordingly, was not included in this survey.

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IRRI is the only center having a formal agricultural engineering department, and the only one having an industrial extension program to promote the manufacture of equipment developed. The volume of work in agricultural engineering, and its impact, is much greater at IRRI than at any other center. The program is concerned primarily with rice mechanization for the small-scale farmer, and more recently, the development of equipment for rotational crops. It is led by an agricultural engineer and has a staff of three senior agricultural engineers, one senior economist and a number of associate and junior staff.

Most centers have outreach activities by which they strengthen and collaborate with national organizations for research and development. Currently, only IRRI has agricultural engineers in outreach programs. IRRI has, or has had, major programs of industrial extension in Egypt, the Philippines, Indonesia, Thailand and India (supported by USAID), and in Pakistan and Burma (supported by CIDA). IRRI has supplied equipment, drawings and specifications to national research and extension organizations in many countries of Africa and several in Latin America.

Equipment developed by IITA has been tried in several countries, and is being promoted alongside IRRI-designed equipment in the IRRI Industrial Extension Program. Both IITA and ICRISAT have supplied machines for trials and demonstrations to scientists of other disciplines, and there is good liaison between both centers and local implement companies using their designs.

17.3 Assessing the Impact of Agricultural Engineering Work

17.3.1 Criteria for assessment

The impact of the agricultural engineering component of the work of the centers may be partly assessed by considering the numbers of machines of types sponsored by them which have been manufactured and adopted by farmers. A less direct facet is the extent to which introduction of center-sponsored equipment has acted as a catalyst to stimulate local agencies or manufacturers to produce alternative equipment. There is evidence that this has occurred in Thailand and the Philippines.

Of much greater importance, but much more difficult to quantify, is the extent to which the new technology has led to realization of better yields, increase in cropping intensity, or better use of water and other inputs. For rice exporting countries, reduction of the cost of production may be a key factor in determining further expansion of production.

It must, however, be emphasized that not all of the agricultural engineering work of the centers is concerned with development of new identifiable machinery. A significant part of the work of IITA, for example, has been the investigation of the effect of different methods of forest clearing on subsequent erosion.

It has been general policy of the centers that the designs of equipment developed should be made widely and freely available to small manufacturers in partner countries. In many cases, this has resulted in low-cost production and adequate local service facilities, both of which are of clear advantage to the farmer, but a possibly negative effect has been the discouragement of

larger manufacturers to produce higher quality equipment by modern production methods. In some cases, farmers have been poorly served by supply of equipment of inadequate quality.

It is also necessary to consider the extent to which the work of the centers has stimulated or inhibited agricultural engineering research and development in the national research systems, and the extent to which the centers have been effective in adapting and transferring equipment and technology between countries.

17.3.2 Issues in adoption of mechanical innovations

The typical chain of events leading to the adoption of new agricultural machinery or technology after the completion of the initial research at a center is as follows:

(a) Evaluation and demonstration of the equipment or system in a partner country - preferably in collaboration with national research and/or extension organizations.

(b) Modification of the equipment to suit local farming needs.

(c) Pilot production by local manufacturers, who may further modify the equipment to suit local preferences, and to suit their own manufacturing facilities.

(d) Evaluation of locally manufactured prototypes.

(e) Sales campaign by manufacturer, possibly supported by the extension service, possibly also supported by action of agricultural banks to provide credit to farmers for purchase of the equipment. Often initial sales are made to contractors who serve a number of small farms.

(f) Progressive growth of sales, if the equipment proves successful, by

providing adequate returns to the farmer, distributor and manufacturer.

It is evident that the factors determining the rate of adoption of new equipment or systems are different from and possibly may be more complex than the factors determining the rate of acceptance of new cultivars or fertilizer practices. For instance, it is particularly important in developing countries for collaboration between ministries of agriculture and ministries concerned with manufacture and distribution of equipment and with import of machines and materials. There is often conflict between protection for indigenous manufacturing industry, and freedom of choice by farmers to buy equipment that, in the absence of protection and its distorting prices, would otherwise be judged as both appropriate and cost-reducing.

Machines or systems developed at the centers can be freely adopted by farmers only when the necessary equipment is manufactured and marketed in significant quantities and when the farmer (or contractor serving the farmer) has the cash or credit with which to purchase the equipment. Even if equipment and finance are available, farmers will only adopt the technology if they are aware of the technology and if they are convinced that it will bring benefit to do so, taking into account the risk of failure and anticipated rate of return on investments. The rate of adoption may be affected positively by adverse weather conditions if the prospect of crop loss can be mitigated by use of machinery or may be affected negatively by low crop prices.

Benefits to farmers generally arise from lower costs for a particular operation, but may also arise from the capacity to intensify land use and thereby produce more crops in a given time. In the usual case a machine replaces either manual or animal power, thereby saving the farmer the costs

associated with those inputs. Where the manual labor so saved is farm family supplied, the result is an increase in welfare for the family, but where the labor was previously hired, the farmer's gain is offset by a loss of employment by hired laborers, often female. These and related equity consideration are explored in greater detail in chapter 8.

The manufacturer will produce the equipment in quantity only if convinced that a suitable market exists or can be developed, and if the investment in manufacture of agricultural machinery compares favorably with alternatives. Widespread adoption of the equipment may be seriously delayed if manufacture is of poor quality. Technical assistance to prospective manufacturers can, therefore, be a vital component in eventual success.

The period between completion of the initial development of a machine by a center culminating in the issue of designs of prototypes for trials in national programs, and the widespread adoption of the technology, is unlikely to be less than five years even in the case of technology that merely changes one step in an existing crop production system. Where more drastic changes are required, the period is likely to be much greater. Thus the rate of adoption is determined not only by the degree of change required in order to produce tangible benefit but also by the resources deployed to promote the new technology, and the technical assistance available to manufacturers to produce the necessary equipment.

It is convenient to classify the developments according to some adoption-related aspects as follows:

(a) Technology that can be adopted by farmers without any serious change (at

least initially) in their farming system, and without significant preparatory work, e.g. power threshing machines may replace manual threshing machines that may replace manual threshing without any change to other phases of the farming systems (but with perhaps great impact on female hand threshers!)

(b) Technology for which some improvement in precision of farming practice may be required or for which several weeks of preparatory work may be required; e.g., the IRRI-type rice transplanter needs a carefully prepared seed-bed, and plant stock must be raised in a special nursery. Action by the farmer may be required some weeks before transplanting takes place.

(c) Technology that involves a change of cropping system by an individual farmer e.g., rotary-injection-planter-no-till technique for planting through mulch, coupled with the control of weeds by herbicides, requires adoption of a more complete cropping system.

(d) Technology that may be effective only if adopted by a number of farmers simultaneously; e.g., the ICRISAT broad-bed and furrow system may, in some cases, be effective only if a number of farmers adopt it in order to provide a unified water control system for a catchment area.

17.4 Agricultural Engineering at IRRI

IRRI is unique among the centers in that it has had for many years a strong and distinct Agricultural Engineering department staffed by engineers and economists. This department has sought to identify restraints to increase yield, cropping intensity and efficient use of inputs and to select those problems which might be amenable to solution by introduction of new mechanical technology or better application of existing technology. Equipment has been

developed at IRRI and trials and demonstrations conducted in farm situations in many countries. Courses have been provided for staff of national research systems, extension workers, and for staff of potential manufacturers. Of major importance has been the industrial extension program in S.E. Asia, strongly supported by USAID and CIDA.

Agricultural engineering started at IRRI in 1962. The main initial activities were the evaluation of imported tractors and machines, and study of the mechanization needs of rice farmers in the Philippines. In 1967, emphasis was changed towards design and development of machinery appropriate to small rice farms in Asia. A wide range of machines has been investigated. These include: lightweight hand tractors (power tiller), axial flow threshers, a rice transplanter, a power weeder, a stripper harvester for rice, an inclined plate seeder, a multicrop dryland seeder, a rice hull furnace for rice driers, an axial flow pump, a seed and fertilizer applicator, a reaper for hand tractor, and root-crop chipping machines. Of these, a few have achieved some commercial success, the most noteworthy being the hand tractors, the threshers, and the power weeder. The declared purpose of the program was to develop equipment to fill the technology gap between animal or manual equipment, and the large mechanized equipment available from industrial countries.

17.4.1 Power tiller

The power tiller was the first major machine developed at IRRI and did not directly match the aims of the program since it took a commercially available imported light power tiller and modified it to facilitate local manufacture in small workshops. The first models were released to manufacturers in the Philippines in 1972, and were rapidly adopted both by

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some small companies, and by some larger manufacturers using mass production methods. Local manufacture of the IRRI power tiller had a catalytic effect, and a number of manufacturers produced their own variants, some simpler and some more complex than the IRRI design. Monge (1980) records that, in 1972, a total of 1400 power tillers were sold of which only 24 percent were locally manufactured. In 1978, 9300 power tillers were sold, of which 70 percent were locally manufactured. Manufacturers who agree to collaborate in the Philippine Ministry of Agriculture-IRRI Industrial Extension Program agree to submit prototypes for quality test by IRRI, to inform the Program of annual production, and to refrain from patenting modifications of the equipment. Some manufacturers, therefore, do not formally acknowledge collaboration with IRRI. In 1975 and 1976, collaborators made more than 40 percent of the power tillers manufactured in the Philippines but, by 1978 this had fallen to 12 percent. In 1981, collaborators made 1100 power tillers but, in 1982, when an improved version was introduced, collaborators produced 2300 units. It may be inferred that collaboration with IRRI is most highly valued during the initial years of introduction of a new machine. Thus the numbers of IRRI-designed hand tractors produced and acknowledged in the Philippines represents only a small part of the total impact of the IRRI work, both in design of the equipment and in extension to manufacturers of the initial technology.

After initial adoption in the Philippines, the IRRI power tiller was introduced in Thailand. Several manufacturers took up the design with some initial success but it was generally considered not entirely suitable for the Thai conditions, and alternative models were evolved by local manufacturers in Thailand. Some of these companies make both pedestrian controlled (hand tractor) and ride-on (4-wheel tractor) versions of the same basic machine. Several of these manufacturers in interviews freely stated that the initial

growth of their companies, from village workshop to factories producing several hundred hand tractors each month, had been based on two years experience and profits earned in manufacturing the IRRI design, before developing their own hand tractor better suited for the local market. In 1983, approximately 20,000 small tractors, 7 to 16 hp, were manufactured in Thailand.

In Indonesia, the adoption of the IRRI-type hand tractor has been slow. In the period 1979-83, 2020 tractors were produced, but 1660 were produced by one company only and 160 by another company. It is believed that most, if not all, of this production was to supply government orders, and neither company has since produced IRRI-type machines. Some 60 percent of the hand tractors sold in Indonesia are of Japanese design, of which 15 percent are imported and 45 percent made locally under license. The remaining 40 percent of hand tractors are of local trademark using engines imported from Thailand or Japan. Present production capacity exceeds market demand. National estimates of hand tractors necessary to meet agricultural production targets was 19,200 units for 1984. In fact, only 6400 were produced and it is reported that only about 2400 of these were sold. It also appears that market demand is for a hand tractor with powered rotary cultivator (as is usual with the Japanese designed machines). Prototypes of the IRRI hand tractor adapted to operate a rotary cultivator are available but the cost of production might not be competitive. The relatively low cost and abundant supply of labor in Indonesia means that alternatives to power machines are still less costly. It therefore appears unlikely that the IRRI hand tractor or any other similar tractor will have significant impact in Indonesia in the near future.

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In Bangladesh, a parastatal company, the Bangladesh Machine Tool Factory, manufactured approximately 200 hand tractors to IRRI design in 1982. Few machines were sold because quality of manufacture was not adequate, leading to unreliability and difficulty in operation, and because local preference is for a machine with a powered rotary cultivator. Subsequent work by an IRRI consultant solved the immediate problems, but production has not been resumed and the IRRI power tiller has so far made no impact. There are reported to be several thousand imported power tillers in use in Bangladesh for tillage and transport. Import of power tillers has recently been banned, although there is reported to be a shortage of animal power for cultivation, and delay in cultivation usually results in reduced yields.

In India, IRRI-type power tillers have been made by the National Engineering Co., Madras, for about five years. Production is believed to be 2300 per year. A few IRRI hand tractors have been introduced to Tanzania, Sierre Leone, Nigeria, Liberia, Cameroon, and Belize. There is no record of commercial manufacture to IRRI designs in these countries.

Although the design features of the chassis of the IRRI hand tractors have been accepted in many countries, it is notable that in nearly every country it was reported that the design of wheels is unsuitable for local conditions, and that redesign of wheels had been necessary. Typically, such redesign was carried out in an ad hoc manner. It is necessary to match wheel design to soil type and condition, but it should be possible to cater for most needs by provision of a few patterns for trial, as there has been substantial work on wheel design by centers other than IRRI. It appears unnecessary that wheels should have to be re-invented in every country!

There is no clear evidence that the development of the IRRI power tiller has significantly benefited large numbers of farmers. In several countries it has encouraged the growth of an indigenous agricultural machinery industry but, in each country, most production is by a few companies each capable of producing several hundred units per month and supplying them through local distributors. More sophisticated designs of hand tractor, either imported or made under license, account for a substantial share of the market in those countries where imports are allowed. It is, therefore, arguable that transfer of design and manufacturing technology could equally well have taken place if official support had been given to programs of manufacture under license of proven commercial designs in the various countries. There is, however, no doubt that the introduction of the IRRI power tiller did stimulate the development of local manufacture of agricultural machinery, and that, especially in Thailand, this industry has developed designs well suited to local conditions.

17.4.2 Axial flow thresher

The axial flow thresher was developed at IRRI in the period 1967-72 to meet a need identified by the farmers for a mobile, lightweight thresher, as an alternative to either very labor-intensive manual methods, or the capital intensive large "McCormick" threshers then used by contractors in the Philippines. The axial flow design has been outstandingly successful and has been widely adopted with more than 25,000 sold. It is well suited to manufacture in small workshops, since there are no parts requiring good surface finish for oil seals, and few precise critical dimensions. The machine is especially attractive to contractors because, at harvest, the farmers have money or grain to pay for services.

In the Philippines, the use of the machine is made especially attractive by the practice of charging for threshing and cleaning the grains as a share of the crop. A similar practice applies in Sumatra where the machine has recently been introduced. Pay-back time for the purchase of the machine is therefore quite short.

Where threshing and cleaning by manual methods is traditionally paid for at wage rates rather than as a share of the crop, the charge for machine threshing is usually at a comparable cash rate. Since it is practice for the farmer to feed the threshing team, and there is a substantial reduction in the time required, there is a resultant saving to the farmer of approximately 20 percent of the threshing cost. The farmer (but not the traditional gleaners) may also benefit from the use of the thresher by a reduction in crop losses. This benefit has been estimated at 40 kg/ha based on farm surveys by Toquero et al., and at 290 kg/ha at the IRRI experiment station.

Most threshing in Sri Lanka is achieved by rolling the crop with a wheeled tractor on a threshing floor. In 1980, the IRRI thresher was introduced via the National Research Station at Maha Illuppallama and by participation of representatives of industrial companies participating in a manufacturers' course at IRRI. Two manufacturing companies were interested in the machine, but neither considered it quite suitable for Sri Lankan varieties, and each company conducted trials over the next two years.

In 1983, unseasonal rain made threshing by traditional methods difficult and subject to heavy losses. There was then a sudden demand for axial flow threshers to which the companies were able to respond. Approximately 800 machines were sold in 1983/84. These machines were heavily used and threshed

about one-third of the crop in the S.W. wet zone (where the wet conditions were most serious). Many of the operators also migrated with their machines to follow the slightly later harvest in the intermediate zone.

There are no accurate records of the amount threshed, but reports indicate that average use was 30 ha per machine per season - say, 120 t/season. Since there were about 500 machines in use over the two critical seasons, it is likely that the machines threshed about 100 kt of rice, with a possible saving (under such adverse conditions) in excess of 10 kt. Without the advent of adverse conditions it is likely that the sales of threshers would have been much lower. It is believed that the use of these machines resulted in a significant saving of crop under very adverse conditions.

The IRRI-type thresher and its local derivatives are used very widely in Thailand which has about 20,000 threshers. Many machines incorporate modifications to accommodate other crops. Many machines are now over four years old, and there is now a demand for replacement or rebuilding of old machines as well as a continuing demand for new machines. In Indonesia with only about 1000 threshers, the introduction of the axial flow thresher is having a significant impact in W. Java (about 600 threshers) and in areas such as W. Sumatra. Here it is meeting the immediate needs of the farmer for a more efficient method of threshing, is overcoming a serious seasonal labor shortage, and is stimulating the development of an indigenous agricultural machinery industry. A number of manufacturers produce machines both for sale and for use under contract hire. The IRRI designs were not entirely suitable for conditions in Pakistan, and a larger multi-crop thresher was developed under the IRRI-PAK program. Over 1000 of these machines have been sold, but many farmers consider it unsuitable for wheat since it does not shred the

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straw to form bhusa for animal feed. The market is therefore dominated by alternative local machines which, while cruder and more extravagant in power consumption, do provide the straw in the condition required by the farmers. Direct data for the proportion of all threshing done by IRRI-type machines are not available but are estimated as about 23 percent in the Philippines and 17 percent in Thailand. The thresher has not been adopted in Bangladesh where manual and animal methods dominate.

17.4.3 Rotary power weeder

This machine was developed at IRRI from the Japanese rotary push weeder. The IRRI-type machine was adopted in Japan and it is reported that, in the period 1975-84, 281,000 machines were produced. So far as is known, this machine has not been adopted in any other rice growing country in Asia, possibly because it can be utilized only if the crop is grown in parallel rows. It may, therefore, yet be adopted in other countries when multi-row drilling or mechanical transplanting is adopted.

17.4.4 Multi-row transplanter

Work has been conducted at IRRI over many years to develop a satisfactory manually operated rice transplanter. It has been necessary to develop not only the machine but to establish a regime for the preparation of plant beds, production of nursery plants of standard size and in suitable medium, and water control. Earlier machines were very sensitive to variation in any of the planting conditions. More recent models are less sensitive.

The only area where the device has been successfully adopted is Libmanan, Camarines Sur, Philippines. Here an irrigators' association bought a number of machines after successful demonstration at their site. Training

was provided for local manufacturers and machine operators, and in production of seedlings. The equipment has now been in use over two seasons and appears to be established, and demand is growing.

In Burma approximately 1000 transplanters were ordered by the government for sale to farmers. Due to problems of quality control in manufacture, and difficulties in extension, the machines have not been accepted, and only a very few have been taken up by farmers. Two machinery companies in Sri Lanka have conducted trials over two years with modified versions of the transplanter. These companies plan to commence production if and when economic conditions are favorable. The transplanter is an example where the change of technology from existing practice is sufficiently great as to require substantial extension effort to introduce the new equipment.

17.4.5 Axial flow pumps

This is an example of technology transfer through IRRI. The design originated in Thailand where many thousands are in use, and has been extended by IRRI (with some improvements) to other countries, notably to Indonesia where, by the end of 1981, some 1600 units had been sold. Since these pumps are made by many small manufacturers usually by copying other units, it is not possible to obtain reliable figures for current production, but these pumps are becoming very common in swampy areas for moving large quantities of water over small vertical distance (i.e., low-head conditions).

17.4.6 Rice driers

Although there appears to be a strong technical case for the introduction of rice driers in order to reduce post-harvest losses of quantity and quality, the adoption of the IRRI design has been slow - possibly because

the benefits to the farmer are modest and so the return on capital invested in such dryers is small, and because the premiums and penalties relating to quality and moisture content are not clearly reflected in farm level prices. The size and capacity of the driers, and uneveness of demand for their use, also dictates that they would be of interest mainly to large-scale farmers, farmer cooperatives, or to grain merchants. Suitable driers already exist to meet the needs of the larger scale farmers and of the grain merchants. The IRRI-type drier is therefore suited to the needs of only a small sector of the industry. The impact is small and is likely to remain so.

17.4.7 Fertilizer placement

In the mid 1970s, equipment was produced to place granular fertilizer in the mud to prevent loss in irrigation water. Agronomy trials over many years showed erratic response to fertilizer placed in this way. Detailed studies in 1983/84 have shown that much of the fertilizer was not retained where it was placed. Improved equipment has now been developed. Potentially, it could result in substantial savings of fertilizer, but it is not yet clear that the financial benefit to the farmer is sufficient to encourage change. The information gained through this work may be 'banked' until a shift in energy and fertilizer prices makes added economy in fertilizer use attractive to the farmer.

17.4.8 Extension

IRRI provides a strong source of agricultural engineering information for research stations in Asia. This has been complementary to, and in parallel with, the work of the Regional Network for Agricultural Machinery which also has a headquarters office at Los Banos. The image of IRRI has, to some extent, overshadowed the extension activities of the network, which was

established some 15 years after IRRI and is coordinated by United Nations-related agencies.

In Pakistan, the establishment of the IRRI-PAK agricultural machinery program led directly to the establishment of the Agricultural Machinery Research Programme of the Pakistan Agricultural Research Council, and to the foundation of the Pakistan Society of Agricultural Engineers. These two events have provided a sound basis for development of agricultural engineering in Pakistan. The impact in this case has been large. In other countries, where IRRI has had industrial extension or cooperative programs, the impact has been less.

17.4.9 Gender issues

Although a number of items of equipment, such as the weeder, relate to tasks carried out typically by female labor, the agricultural engineering department of IRRI in the past has not investigated the impact of its equipment on female labor productivity, employment, or the allocation of tasks between men and women. For those tasks in which women typically predominate in traditional agriculture, little attention has been paid to the potential for adapting equipment design to women's physique.

17.5 Agricultural Engineering at IITA

The Agricultural Engineering Section works within the Farming Systems Programme of IITA. In the late 1960s, the section tackled a wide range of agricultural engineering problems. This led to a selection of a few activities that have been further developed to enhance farmer and manufacturer

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acceptance. The most striking developments have been related to minimum or zero tillage, and to crop harvesting.

17.5.1 Minimum tillage cropping

Techniques have involved the use of live and dead mulches, and alley or avenue cropping. In appropriate areas, the technical advantages of such systems for erosion control and maintenance or improvement of soil structure, fertility and moisture availability, have been shown to be high compared to conventional tillage practices. However, establishment of such systems requires a drastic change of farming practices as well as heavy investment, and adoption of the systems on farms has been limited and slow.

To facilitate the use of mulches, it was necessary to introduce equipment able to plant through mulch. An early American design of 'walking stick' planter was formalized as an IITA hand-held jab planter, and further developed with an automatic feed. Drawings of original improved versions were made freely available in 1976. This equipment could be used even with conventional primary tillage but there is no evidence that it has been widely adopted. This may be because farmers were not convinced of its advantages or perhaps because the necessary information has not been published in a form easily usable by extension workers and lead farmers.

The principal of the rolling injection planter (RIP) was brought to IITA by a VITA volunteer (the late George Banbury) in 1977. The machine was developed and simplified by IITA engineers. It is demonstrably the simplest and most effective means of planting through mulch or surface trash. It is versatile, and can plant maize, rice, wheat, sorghum, and cowpeas. Designs and prototypes were made available in 1979, and have been widely distributed

in Africa and have been evaluated by IRRI for Asian conditions. There have been over 500 requests, including 65 in 1984, for plans of the planter. Samples or drawings have also been supplied to other international centers.

The Technology Consultancy Centre of the University of Science and Technology Kumasi, Ghana, became interested in no-till injection planter and no-till technology in 1977. Realizing that prolonged and effective demonstration would be required for the technology to be accepted, it established a special farm for trials, demonstration and for training farmers in this system, and also published a handbook of the system.

There are conflicting reports of the number of RIP units manufactured in Nigeria. Production by manufacturers is believed to be approximately 3500 single-row units, and a further 1500 units may be incorporated in multi-row machines. There may be additional production by other manufacturers who have not advised the center of their activity. As a result of testing, the Kenya Ministry of Agriculture has sponsored the production of several thousand planters, many of which will be used with animal draught.

Rate of adoption of the rolling injection planter has been constrained by inadequate quality of manufacture by some companies. Feedback from users indicates a need to improve the seed-metering device, and to reduce the effort to push the machine. Successful operation in a no-till situation also requires control of weeds by herbicide, an aspect that does not appear to have been successfully passed on to users.

Multi-row versions of the rolling injection planter have been produced including; two, three and four-row versions for hand operation, and three to

six-row version for use with animal or hand tractor operation. Prototypes of larger guaged units for use with four-wheeled tractors are being tried. The true success of the multi-row version is not known since nearly all were produced as a single order for 350 four-row machines for a government contract, and there have been no repeat orders.

17.5.2 Harvesting machinery

Harvesting of maize and cassava, and recent work on threshing of rice, constitute a second field of activity. Over the seasons of the late 1970s, trials were conducted on three proprietary, tractor operated, cassava lifters, and of one root-loosening device of CIAT design. The trials indicated that two of the proprietary implements were inherently unsound, that the third had some mechanical defects, and that the labor requirement of the CIAT device was high. The work was well conducted but did not lead to any specific resolution of problems identified. The impact of this exercise, if any, had been limited to discouraging the introduction of unsuitable equipment.

A lightweight simple and low-cost aid to hand pulling of cassava was developed in 1978. One company made 300 units against a government order. The tool is seemingly being used on several large cassava farms in Nigeria. This appears to be a case where the tool is technically effective but where the farmer has not been convinced of the advantage over alternative methods. There has been some transfer of information that has led to manufacture of similar devices in Thailand, but it has not been possible to ascertain to what extent the tool has been adopted there.

17.5.3 Land clearance

Trials of alternative methods of mechanical land clearing have shown that clearing with a shear blade does far less damage to the soil than does clearing by root rake or root plough and that the cost of mechanical clearing is only about 25 percent of the cost of clearing by hand. This work is of major importance in view of increasing pressures to clear forest land for permanent cropping. The impact will be achieved when the information is accepted by planners and managers of land development programs and they adopt methods that best protect the soil.

17.6 Agricultural Engineering at ICRISAT

In the Farming Systems Programme of ICRISAT, work has been directed to evolving economic and sustainable farming systems which will conserve water and soil and require modest energy inputs. The Farm Power Equipment sub-programme has given priority to the development of equipment to facilitate the adoption by farmers of the broad bed and furrow system (see chapter 7). This has involved work to improve and evaluate animal-drawn wheeled toolcarriers and an associated range of implements for cultivation, seeding, fertilizing and weeding. This associated equipment may be used with equal facility for traditional cultivations on the flat or on ridges. Other studies have been concerned with threshing, drying and storage of cereals. Projects to investigate machinery and cultivation systems as components of improved crop production packages for local agriculture, although well formulated, are not yet at a stage where meaningful results may appear. Wheeled toolcarriers of the types sponsored by ICRISAT are being tried in Niger and Mali and other countries of W. Africa and Latin America under bilateral technical assistance programs.

17.6.1 The animal drawn toolcarrier

Initial work in 1974-75 was directed toward the evaluation and improvement of wheeled toolcarriers for cultivation on flat or ridged land. The subsequent evolution of the broad bed and furrow system indicate a need for appropriate implements in order to make it practical and economic. In collaboration with Jean Nolle (France) and the National Institute for Agricultural Engineering (UK) improved toolcarriers and associated implements were established from 1979 to the present. Trials on several soil types have indicated that the system may be best suited to use on Vertisols, while on Alfisols cultivation on ridge or flat may give better yields. Extension of the system must be selective according to soil type, slope and rainfall pattern. A technical advantage of the system is that contour bunds may be unnecessary in which case existing bunds could be removed to bring more land into cultivation. However, as with all systems requiring a drastic change to farming practice or infrastructure, the rate of adoption is slow and very dependent on the effectiveness of the extension service. The introduction of the system may be further complicated by the shape and distribution of farm parcels since, ideally, the system should be applied by all farmers within a minor catchment area.

Recent trials at Hyderabad have shown that the system can be applied even within bunded areas. A further constraint to the implementation of the system using the animal drawn toolcarrier is the capital cost involved in the purchase of the toolcarrier plus a full range of implements. There has been little study of alternative methods of building and working the system with cheaper implements to permit phased adoption of the components of the system. The wheeled toolcarrier is, in practice, used mainly for level or ridged land

cultivation or as a cart. Technical assistance from the UK, and financial assistance by government purchase or subsidy, has promoted manufacture of wheeled toolcarriers by several Indian companies. The total local production of wheeled toolcarriers of both types fostered by ICRISAT ("Tropiculture" and "Nikart"), is of the order of 600 units.

The impact of the wheeled toolcarrier has been small and its use for the broad bed and furrow system is likely to grow slowly. It is unlikely that the system can be introduced as a 'package' over any significant area in less than about ten years, but adoption would be facilitated if a phased application of the components of the system were possible. For those who have already acquired toolcarriers, the transition to the fuller system requires little additional investment.

17.7 Agricultural Engineering at Other Centers

17.7.1 ICARDA

A part-time mechanical engineer was engaged in development of a lentil harvester under a German Technical Aid Programme 1983/4. In 1983, ICARDA collaborated with the Syrian Ministry of Agriculture to offer training courses in mechanical harvesting of cereals and legumes, and mechanical planting of field crops. A survey and economic analysis of food legume crops showed that there is need for better weed control and for mechanization of harvesting, (the present high cost of which is a major constraint to increased production of lentils), and that soil degradation is a major problem. Other mechanization works in hand include precision planting of chickpeas and faba beans and threshing of medics and dry faba beans.

17.7.2 WARDA

Of WARDA's research stations, only the Mangrove Swamp Rice Station at Rokupr in Sierra Leone could be visited. WARDA shares the site with the Rokupr Rice Research Station, the FAO WARDA Rice Mechanization Project and the Adaptive Crop Research and Extension Project.

Trials over three years with Honda six hp hand tractors have indicated that the use of rotary power tillers for puddling is power-consuming and slow. Ploughing by hand tractor can provide good weed control and is economic if undertaken at the right time. Only a very light machine can be used as it is necessary to transport the tractors in small boats. In collaboration with the Regional Integrated Agricultural Development Programme, arrangements have been made for groups of farmers to share the use and costs of a tractor and plough. Several hundred farmers will be involved, but the impact is yet small and may be difficult to extend far from Rokupr.

Agronomic trials have shown excellent crop response to injection of urea, but the injection technique is laborious, and so far there has been little adoption. Actual response in farmers' fields and economic benefit is not yet confirmed. The system does, however, use equipment that may also be used for pest control, and could be readily adopted. Parallel work on fertilizer injection planters at IRRI may, if successful, overtake this work.

17.7.3 CIMMYT

There is no agricultural engineering research program at CIMMYT. The only machinery development has been the design and manufacture of a minimum tillage seeder for maize and sorghum as an exercise in a training course for

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Research Station Managers. CIMMYT has prepared for interested national organizations full details of the seeder. This information is presented in an exceptionally clear manner so that the machine may be easily reproduced and evaluated wherever its use appears appropriate. In 1983, details of the prototype were supplied to the Agricultural Engineering Department of INIA, Mexico. There has yet been little feedback from national organizations, and there is yet no impact at farm level.

17.7.4 ILCA

Part of the work of ILCA is concerned with draught animals, including crossbred types, and their more efficient utilization. Studies on the matching of implements to pairs of animals, and alternative harnessing to permit use of single animals instead of pairs, are of too recent origin to have yet had any significant impact. Work to improve the ancient plough and make it more suitable for single animal use is likely to be directly of use in the local area. A national program has been initiated in Ethiopia between ILCA and the government to promote the use of ox-drawn scoops for creating small-scale water-harvesting storages. The work grew out of ILCA's development work and recent successful on-farm testing of techniques to make efficient use of out-of-season draft power.

17.7.5 CIAT

Currently agricultural engineering work is limited to a pilot project for the chipping and drying of cassava by small scale units in the north of Colombia (see chapter 7).

17.8 Coda

* The proportion of CGIAR effort allocated to agricultural engineering has been low.

* Except at IRRI, the engineering work has been as components of a Farming Systems Research Program. The impact of this work is necessarily long-term, and is difficult to quantify. The effect due to agricultural engineering research cannot be assessed separately from that of others in the multi-disciplinary team.

* Some of the equipment development of the centers has been very effective. Power tillers and axial flow threshers developed at IRRI have been widely adopted and the rolling injection planter developed at IITA shows great promise.

* In most of the developing countries, the national institutions and extension services concerned with agricultural engineering are weak. Technical information from the centers has not always been presented in a suitable form and, in some cases, has been either poorly understood or poorly applied.

* Significant adoption of equipment designs produced by center engineers has been achieved only where it has been supported by a program of industrial extension. Most of this work has been assisted by other aid agencies.

* Even with strong assistance to industry, the lead time to introduce new

equipment is long: say, two years minimum for equipment that may be introduced without change of farming system, otherwise ten years may be more typical.

18 BIOLOGICAL NITROGEN FIXATION

The material for this chapter was not in final draft form at the time that this report was circulated to members of the Consultative Group. It is based on a report yet to be finalized by Dr. Jake Halliday of the Battelle-Kettering Foundation (previously Director of the NIFTAL Project).

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NOTE: This chapter is as it was drafted for the consideration of the Advisory Committee in July 1985. There was insufficient time to undertake the suggested further work, including sensitivity analysis of the investment analysis of the selected pipeline innovations as well as additional information provided by the centers.

19 FUTURE IMPACTS

19.1 Introduction

Investment in research has produced advances which have in the past clearly justified the use of the resources. This past experience is undoubtedly an important guide to the returns that might be expected from current and future investment in research. The increase in research expenditures by developing countries over the past decade surely reflects, in part, the historical record of high average rates of returns. The overall record, however, conceals considerable variation in the return to past investments, and is hardly replete with analyses of failures. As such it can only serve as a partial guide.

Furthermore, it might be argued that future returns from investment in the centers cannot be expected to match those achieved in the past. In wheat and rice, from whence came the major early achievements, it may be that each successive advance becomes more difficult in terms of research challenge and the diffusion slower and more costly. In addition, as the CGIAR system has grown, it has embraced other crops and focused greater attention on harsher ecological settings, raising questions about the future impact. Given the long lags in research, commitments have to be made today to fund research whose major impact may be 15 or 20 years hence. Careful consideration should thus be given to the magnitude and dispersion of the expected contributions.

The long-range planning reports of the centers contain at least implicit statements about expected returns. This chapter is an attempt to make some aspects of those plans more explicit and to illustrate the scope and magnitude of expected net benefits. Some will argue that such an exercise is so fraught with uncertainties that little of use can be said. It is true that a number of assumptions must be made. By its very nature, investment in research involves long lags; five to ten years may be needed to develop a new technology and a further 10 years may lapse before it is widely adopted and significant benefits are realized. But investment decisions must be made, and some indication of the likely payoffs provides, at the very least, a crude device for screening the more from the less promising.

This chapter comprises two major sections. In the first, some highlights of forthcoming technologies from some of the centers are presented. In the second part, a more detailed and formal analysis is undertaken of a few selected cases. The limitations of this exercise should be made explicit at the outset.

(a) Primary reliance is placed on estimates of the gross value of additional production in the crop under consideration, although a crude attempt is made in the case studies to allow for any increased costs of other inputs .

(b) Each case is treated separately and no allowance is made for the effect on production or consumption of other crops, given technical change in a particular crop.

(c) In all cases bar one, no attempt is made to assess the future impacts that might be associated with different levels of funding, so that

conclusions cannot be drawn about whether maintaining the current level would imply over- or under-investment.

(d) There is no attempt to consider the distributional consequences, except in so far as these are implicit in the choice of crops or the regions being addressed.

(e) No allowance is made for any possible external effects from research on one crop in one region on other crops in other regions.

(f) All countries are assumed to face given world market prices for all crops which are treated as tradeable goods, and the output changes of any country are assumed to be too small to influence the world price. The long-run evidence of declining real world prices stands in apparent contrast to this assumption. However, it is of more significance for determining the distribution rather than the size of the benefits from technical change.

(g) In some places, an attempt is made to reflect the relative likelihoods of success but these should be taken only as crude indicators of the uncertainties involved.

(h) The list of centers and commodities is incomplete, so that those presented reflect a selection biased toward the more likely and substantial successes.

19.2 Developments Forthcoming from the Centers

19.2.1 Future impacts of research at IRRI

The magnitude and distribution of the future impact of IRRI's research reflects the allocation of its research resources. This allocation is determined by four considerations:

(a) The expected return to research in difference rice cultures (an efficiency objective);

(b) The distribution of the impact (an equity objective);

(c) The comparative advantages of IRRI and national programs in the conduct of research on the rice plant, its production and utilization;

(d) The contribution to global rice research through seeds, methods and literature.

IRRI's future impact will come through two channels: collaboration with national programs, and a research focus which results in increases in rice yields and reduced production costs. Future collaboration with national programs will center on aligning IRRI's work to the needs of national programs, through joint research and the exchange of germplasm and information, and through training and workshops.

Through the continued improvement of rice varieties with high and stable yields which have multiple resistance to insects and diseases, and through the increased use of short-duration varieties to intensify rice production, IRRI through its collaboration with national programs expects to contribute additional rice in S. and S.E. Asia worth $16-17 billion per year by 2000. This is assuming that an investment in IRRI of $25m per year is sustained together with that of national programs. Nearly 60 percent of that gross value of extra output would come from the irrigation sector. The results, summarized in Appendix Table 19.1 are clearly conservative estimates of expected contributions, as China, E. Asia, Africa and Latin America have not been included. In 1983, China sowed 6.75 million ha of hybrid rices developed by the Chinese using

restorer lines from IRRI. The hybrids increased output by at least 10 percent, or a total 4.3 Mt of extra rice. Valuing this output at $100/t gives a value of extra production of over $400m in that year, although the majority of this must be attributed to Chinese efforts.

Through a combination of input-efficient rice varieties, improved crop husbandry practices, integrated pest management and soil and water controls, high yields will be sustained and unit production costs will be reduced. The savings from improved fertilizer and insecticide efficiency on rice in S. and S.E. Asia alone are expected to exceed $1 billion per year by the year 2000 (Appendix Table 19.2).

19.2.2 Future impact of research at ICRISAT

ICRISAT has bred varieties of pearl millet with high levels of resistance to downy mildew and ergot disease, and which also yield 20 percent more fodder. The variety WC-C75 has the potential to replace lower yielding varieties on about 3 million ha of land sown to pearl millet in India (about 25 percent of India's area sown to this crop. It seems certain that this variety would yield 70 kg/ha more, producing about 0.2 Mt worth over $20m a year.

Current damage from pod borer (Heliothis armigera) in pigeonpea and chickpea is estimated at $300m a year. The development of resistant strains could reduce this loss appreciably. If resistant strains could halve the current loss from sterility mosaic in pigeonpea, Indian output could rise by 8 percent with a resulting gain of $55m a year.

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Varieties of groundnut resistant to leaf spot and rust are undergoing testing. If they were to be sown on 20 percent of the Indian groundnut area in the rainy season and lead to a 25 percent gain in yield, total returns would exceed $50m per year.

If varieties of sorghum resistant to mold could reduce the mold level by one half, the value of the crop could rise by 3.4 percent or $4.5m a year.

Cultivating 5 million ha of deep black soils in India during the rainy season could raise national income by $800m a year.

An analysis was based on the expected yield increases for five crops principally in India. These estimates reflect the collective judgment of ICRISAT staff and refer to the increase in farm yields by the year 2000 given the current level of research funding. The estimates of the gross value of additional output are based on 1980 areas. The implied annual rates of growth of yields are 3.2 percent for sorghum (3.1 percent in technologies is summarized in Table 19.2. Where estimates of yields are Africa) 3.5 percent of pearl millet, 2.6 percent for pigeonpea, 3.9 percent for chickpea and 4.1 percent for groundnuts. The gross value of additional output in 2000 is estimated to be $7.6 billion (Table 19.1).

An additional estimate was made based on the farm yields which would be expected were the current level of research funding to be doubled. In this case the gross value of additional output rises to $12.4 billion by 2000. Would this additional investment be worthwhile? To answer this

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Table 19.1 Estimate of the future impact of research at ICRISAT on the gross value of output

Crop	Region	1980 Area million ha	1980 Yield t/ha	Price $/t	Expected yield in 2000: With current research t/ha	Expected yield in 2000: With twice as much research t/ha	Gross value of additional output in 2000: Current research $ billion	Gross value of additional output in 2000: Twice as much $ billion
Sorghum	India	16	0.8	150	1.5	2.0	1.7	2.9
	Africa	15	0.6	150	1.1	1.5	1.1	2.0
Pearl millet	India	12	0.5	150	1.0	1.3	0.9	1.4
Pigeonpea	India	3	0.9	250	1.5	1.8	0.5	0.7
Chickpea	India	7	0.7	250	1.5	1.9	1.4	2.1
Groundnut	India	8	0.8	250	1.8	2.4	2.0	3.2

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the return was calculated assuming the additional annual research costs were $20m; no results were forthcoming for 20 years; of the extra output of $12.4 billion, 75 percent would be due to extra inputs and only 20 percent attributable to ICRISAT's efforts. Under these conditions the annual rate of return to the additional funding would be over 20 percent.

19.2.3 Future impact of research at CIP

CIP expects its major future impacts will come from its collaborative networks with national programs, its training and information programs, its use of research contracts for basic studies, improved research methods, integrated pest management, rapid multiplication, the use of true potato seed and improved post-harvest storage and processing. It is important to stress that many of these activities are not aimed solely at increasing potato yields. This underlies the importance of broadening the view of the contribution of the centres in their collaborative programs, not limiting an evaluation solely to the additional area of high yielding varieties. The possible contribution of some selected shown, they refer only to limited seasons and areas of potato production where the particular constraint is relevant; nor are they additive.

19.2.4 Future impact of research at CIAT

Rice Program. Vast areas of infertile soils of Latin America remain underdeveloped. While they have excellent physical traits and many areas receive adequate rainfall, they are highly acidic. CIAT is seeking to develop an upland rice production system which would use low levels of

inputs and achieve moderate yields (2.5 to 3.0 t/ha) for two rice crops, prior to pasture establishment. Screening hundreds of cultivars from W. Africa and Brazil has identified some which are acid tolerant and have resistance to fungal diseases. By combining suitable cultivars with appropriate agronomic practices the Rice Program expects to have a rice production system for these areas within five years.

A major future impact in rice breeding will come from the use of anther culture for the regeneration of plants from the pollen of hybrids. The technique will reduce the time needed in breeding new varieties by three to six years and save research resources. The technique is being used to screen for acid and cold tolerance. Future research will involve introducing selection agents into the culture medium to effect in vitro selection.

Bean Program. Major emphasis to date has been placed on developing a collaberative research network both in Latin America and Africa to generate improved germplasm. Preliminary studies show that, in many countries (among them Argentina, Costa Rica, Cuba and Guatemala), widespread adoption is already occurring at the farm level of new lines characterized by resistance and improved architecture. The resistance is to bean common mosaic virus and anthracrose. These new lines have come both from CIAT's breeding program as well as the horizontal transfer effected by CIAT of existing germplasm between national programs. It is through these improvements that the major impact will come in the short term. Within two years, for example, materials with resistance to bacterial blight and capable of an average yield increase of 10 percent

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Table19.2 Future impact of selected technologies in potatoes

Technology	Notes	Probability 5 = expanding use 4 = highly likely 3 = reasonable chance 2 = some chance	Potential yield increase (where relevant) percent
Rapid multiplication	Use of stem, node, sprout and leaf bud setting to accelerate multiplication of seed in national programs	5	n.a.
Improved germplasm	Bacterial Wilt resistance	5	5-40
	Late Blight resistance (major worldwide disease)	4	10-50
	Heat tolerance	4	30
	Leaf Roll Virus resistance	3	10-50
True potato seed	Offers major advantages of use of seed tubers for areas with abundant labor and scarce land. Can reduce costs of production substantially	5	-
Biological control	Tuber Moth with pheromone	4	20 in field 50 in storage
	Nematode with a fungus	3	15
Viral infection	Detection and elimination material infected with Potato Spindle Tuber Viroid	2	20

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will be available for 700,000 ha of Latin America. The future spread of varieties resistant to bean golden mosaic virus should raise yields by more than 50 percent in much of Central America.

Considerable advances have already been made in developing new lines with multiple disease resistance to raise yields while lowering instability and risk. Within the next few years, it is also expected that new lines with improved drought resistance, nitrogen fixing capacity, low fertility tolerance, and earliness will be released. Moreover, taking advantage of progress already achieved in Latin America, it should be possible quickly to identify superior germplasm for Africa. Research progress on more difficult problems, such as resistance to common bacterial blight and storage insects has progressed to such extent that, in the near future, lines from these research efforts will reach the farm, thereby reducing losses from problems that are otherwise extremely difficult to control.

A summary of future developments for beans is given in Appendix Table 19.3

Cassava Program. Future impact of research by the cassava program will be related to the three main areas of work: improved germplasm, cultural practices and utilization. Improved selections with yield increases of up to 50 percent should be released in Thailand, for example, within two to three years, and this work has a very high chance of success. Gross value of added production would exceed $30m a year even at a conservative estimate of a 10 percent increase in output.

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Biological control of cassava pests has a enormous potential payoff for both Africa and parts of Latin America, and CIAT expects further adoption to prevent substantial losses.

Fungicide treatment of fresh cassava to prevent post-harvest deterioration could expand market demand and reduce distribution costs. In Latin America alone, expanding the use of the technique developed by CIAT is expected to generate total benefits of up to $200m a year within the next five years. Economic analyses of the expected return to such research have shown that this compares favorably to the benefits that can be expected from production technology.

Finally, prospects appear excellent for the continuing growth of small-scale processing plants for livestock feed production, especially in Colombia and potentially in Mexico. Analysis of the expected profitability of cassava production for drying, shows that returns per hectare would exceed those in cattle (the next best alternative) by over $200, even at current yields.

A summary of future developments is given in Appendix Table 20.4.

Tropical Pasture Program. The central contribution of the program will come through expanding the forage germplasm base for the acid lowlands of tropical America (the details are given in Appendix Table 19.5). The key focus of the research will be the development of legume-grass pastures based on germplasm adapted to very acidic and poor

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soils, resistant or tolerant to major pests and diseases, and of higher productivity and persistence.

This is being achieved through the development and use of a large germplasm collection which is the base for the screening process undertaken jointly by CIAT and national programs. Given the size and heterogeneity of the land resources involved, a decentralized screening strategy is being followed throughout the tropical lowlands. On the other hand, more broadly applicable research on agronomy, animal productivity, establishment techniques etc. is mainly undertaken at two major screening sites in Colombia and Brazil (chapter 13).

The impact of the program is expected to be gradual due to the very nature of cattle production, but very extensive in terms of area. Tropical America comprises about 300 million ha of savannas and about 600 million ha of humid forests. The nature of the impact will be very variable ranging from increases in beef output of fattening farms to increased reproductive efficiency in cow-calf operations. In several regions, important increases in milk output are expected from small dual-purpose beef-milk operations. In regions with marked seasonality of forage and large seasonal price differential for beef, legume grass associations are expected gradually to reduce these. While the major impact is expected initially in savanna ecosystems, after a longer time lag, a contribution is expected with respect to more economic and ecologically stable production systems for the humid tropics. Further details are given in Appendix Table 19.6.

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Adoption of improved pasture species is expected to expand from present levels of about 70,000 ha in Brazil and 17,000 ha in Colombia (as well as minor areas in Peru, Panama and Venezuela) as more legumes are released and made available to farmers. These will enable them to reap the full benefit of released grass materials.

Improving the efficiency of cow-calf operations is the most challenging research area due to the harsh economic setting; i.e., long production cycle, poorest soils, largest distance to input and output markets. On the other hand, the low efficiency of existing cow-calf systems is the main bottleneck for the development of these understocked regions. After five years of grazing, on-farm trials evaluating the use of small areas of improved pastures for cow-calf operations have shown that with as little as five percent of the area in improved pasture, stocking and calving rates, and weaning weights have been substantially improved. The annual rate of return to the investment in improved pasture range exceeded 30 percent, although it depended especially on assumptions about its long-term persistence.

The growth of population and income ensure a continued increase in the demand for livestock products. With the concomitant upward pressure on prices, there will exist a derived demand for technical change. The research and adoption phases are likely to be long but given the growing demand and vast areas of land, exceeding 100 million ha in Latin America, the payoff to investment in tropical pasture research should be comparable to, or even exceed, that of crop research. If the enhanced animal nutrition stemming from improved pastures were to result in

improved calving rates of 15 percent within 25 years over 60 percent of the breeding cattle, the investment in tropical pasture research would have a benefit to cost ratio of 15:1.

19.2.5 Future impact of research at CIMMYT

Wheat Program. In the short run, the major future impacts of wheat research are expected to be in the availability of cultivars tolerant to aluminum concentrations and resistant to *Septoria*. Yield gains of 150-200 kg/ha over 10-15 million ha are expected in Brazil and parts of Africa. In the next three to five years, heat tolerant cultivars should increase yields in years of high heat by 15-20 percent, and extend the areas suitable to wheat production.

In the longer term, improved resistance to *Helminthosporium* spp. should stabilize yield on 10 million ha of tropical and humid areas. All these efforts should enhance yield dependability through resistance and tolerance to weather and soil stress. A summary is given in Appendix Table 19.7.

Maize Program. Future impact will come from the expanded gene pools available to national programs, with emphasis on materials widely adapted to their needs defined by attitude, latitude, maturity and grain type. In particular, special attention will be given to problems in certain regions; streak virus in tropical Africa where, within five years, new materials should offer the potential for yield gains of up to 10 percent

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on 10-15 percent of the area. Further details are given in Appendix Table 19..8.

19.2.6 Future impact of research at ILRAD

ILRAD is devoted to research on two diseases (East coast fever and trypanosomiases) which limit animal production in Africa. As many as three million animals die each year from these diseases which also reduce the productivity of surviving animals and preclude ruminants from an area of 10 million km^2. Control of these diseases would allow an additional 120 million animals to be carried.

The objective is to develop vaccines against these diseases. The pioneering nature of this work results in the need for a number of basic scientific studies. These have already resulted in improved understanding of the epidemiological and immunological aspects of the transmission and host reactions to the diseases. The advances that have been made to date represent an expanded stock of scientific knowledge on which future solutions can be built.

The trypanosomes constitute a complex challenge because of the antigenic variation of the parasite. Production of antibodies by the host induces the invading trypanosome to modify its surface structure neutralizing the effect of the antibodies. Over one hundred different surface variations have been recorded. This aspect significantly complicates the development of a vaccine, and justifies attention to other potential solutions. Of particular note are the studies of

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trypanotolerance in different breeds and environments being undertaken jointly with ILCA.

It is expected that, within five to seven years, an improved method of vaccination against East Coast Fever should be available. Such a vaccine created on the basis of sporozoites injected without further treatment would introduce immunity to a wide number of strains. A vaccine fabricated from antigens that cause the immune response and that are produced by infected cells (macroshizosites) can be envisaged in the longer run, perhaps some 10 to 12 years ahead. Finally, a vaccine that prevented the tick attacking and infecting the host would be ideal as it would provide protection against all infections carried by this vector. While some promising results are emerging from the joint efforts of ILRAD and ICIPE, antigens have yet to be produced.

An important indirect potential impact lies in the control of both other species of theilerioses and other tick-borne diseases.

Because of the problem of antigenic surface variation, the probability of successfully developing a vaccine for the trypanosomiases must be viewed as significantly lower. For this reason, the advances are likely to be more modest and occur over an extended period. Within ten years, it should be possible to identify a genetic marker in trypanotolerant animals and progressively transfer that on a broad scale. Improved understanding of the African animal trypanosomiases transmitted by the tsetse fly will aid in all control of other trypanosomiases not so transmitted, as well as provide additional

knowledge for the control of human trypanosomiases. Contributions to parasitic immunology and enhanced knowledge of bovine immunological systems are potentially important products of the research.

Research on control methods other than vaccines requires widespread field and laboratory studies for which the techniques are generally known. In order for these to proceed effectively, ILRAD must have a network of trained collaborators working with adequate facilities in cooperating national programs. Efforts to develop a vaccine will not be allowed to drain attention and funding from the needs of national programs for training, information and research support.

19.2.7 Future impact of research at IITA

Maize. The future impact of the IITA/CIMMYT Africa Maize Program is expected to come from large-scale adoption in Africa of improved open pollinated varieties, and hybrids.

Maize populations with combined resistance to maize streak virus and downy mildew are being improved and, by the early 1990s, should be grown extensively in countries where these two diseases co-exist, including Burundi, Mozambique, Nigeria, Somalia, Sudan, Uganda, Zaire and Zambia.

Populations resistant to stem borers (Sesamia, Eldana and Busseola) and drought tolerant varieties will be available by the early 1990s. Resistance to the parasitic weed Striga has been observed in a few promising hybrids and will have been incorporated into some elite

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populations by the early 1990s. Research in mid-altitude ecologies, which account for 40 percent of African maize production, is being strengthened through the establishment of a joint IITA/CIMMYT mid-altitude station in S.E. Africa.

The initial results of the IITA hybrid maize research have led to the formation of two commercial hybrid seed companies in Nigeria. Future impact of the hybrid maize work will include the stimulation of a strong seed industry, the promotion of livestock development and the attainment of maize self-sufficiency in Nigeria and some other African countries within a decade.

The upshot of the expected achievements outlined above is expected to be a boost in average yields of maize to at least 3 t/ha in the next decade. This would represent an annual increase in production of about 28 Mt worth $4 billion gross at current prices.

Rice. Rice varieties and lines developed or selected by IITA are being grown on about one million ha in the Cameron, Ghana, Liberia, Nigeria, Peru, Sierra Leone, Tanzania and Zambia. Further adoption is expected during the next five years. Elite lines including ITA 212, ITA 235, and ITA 257 which are high-yielding and have durable resistance to the rice blast are being tested in 15 countries. Breeding for stable high yields, resistance to major diseases, insect pests, soil stresses, low temperature and acceptable grain quality is being intensified.

The new International Rice Testing Program for Africa unifies and rationalizes the African testing programs of IITA, IRRI, IRAT and WARDA and should accelerate the development and adoption of improved varieties. Moreover, research being conducted by IITA's Farming Systems Program on the management of wetlands will make more suitable rice-growing land available. This development coupled with the testing program and further adoption of varieties already released should provide a basis for Africa to become self-sufficient by the year 2000.

Cassava. Cassava clones developed at IITA or based on IITA material are currently grown on about 1.5 million ha in twelve African countries. With the development of the tissue culture technique and as links with national programs are strengthened through training and collaborative research, these clones should spread to 5 million ha by the early 1990s. This would generate additional annual gross income of about $9 billion to African farmers every year at current prices.

Future impact will also come from wide crossing which could increase cassava yields by 25 percent. The substitution of cassava flour for some imported wheat flour could occur over the next decade. Considerable variability exists among cassava clones in their suitability for bread making. Some nutritional impacts may result from work on breeding cassava clones with yellow flesh providing higher carotene content than present clones.

Initial results from the two-pronged attack on the mealybug and green spider mite have been promising. Clones resistant to these pests have

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been identified and are being incorporated into high yielding and disease resistant clones and populations. Natural enemies of the mealybug and green spider mite have been introduced from Latin America in collaboration with CIAT, reared and released experimentally in various countries. These releases will be carried out throughout the cassava growing areas of Africa. Effective control of these two pests, which cause severe damage, may be achieved within the next five years.

Sweet Potato. Sweet potato clones developed at IITA or selected from IITA germplasm are being grown widely in twelve countries. The higher yields of improved clones have resulted in their introduction in S.W. Nigeria. Such introductions can be expected to spread.

Future impact will come from the incorporation into elite clones of resistance to the sweet potato weevil, the crop's most damaging pest. In addition, sources of resistance to the sweet potato virus have been identified and the genes are being introduced into elite clones. Combined resistance to weevils and the virus complex, coupled with the rapidly increasing spread of the improved clones could boost average yields from their current level of 6.5 t/ha in Africa to 15 t/ha on about 1 million ha by the mid 1990s.

Yams. Traditionally, about 2.5 t/ha of seed yams are required for planting. This represents 20-30 percent of the total harvest and constitutes one third of the total cost of yam production. The minisett and microsett systems of seed yam production require only 0.5 and 0.1 t/ha, respectively, for planting. Seed yam yields of up to 40 t/ha

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can be obtained in five months and net profit to the seed yam grower at current prices is estimated at over $10,000/ha. The technology is being rapidly adopted in Nigeria where a seed yam growers' association was formed in October 1984.

Yam area has hitherto been limited by the scarcity and cost of planting materials. The minisett and microsett systems will remove this constraint. As a result, the area grown to yams could increase by as much as 50 percent from the current 2.5 million ha worldwide by the mid 1990s. Average yields will increase by about 30 percent because of widespread use of good quality planting materials made possible by this new seed yam multiplication technique.

Additional sources of future impact are expected to include the development of stakeless ware yams, the breeding of resistance to nematodes which provide inroads for the organisms which cause yam rots in storage, and the development of yam cultivars with uniformly shaped tubers amenable to mechanical harvesting.

Cowpea. IITA has developed many cowpea varieties with multiple disease and insect resistance and extra-early maturity. They have been released in 31 countries in Africa, Latin America, Asia and the Caribbean. The Grain Legume Improvement Program is currently strengthening its linkages with national cowpea programs worldwide through placing staff in various countries; through training at IITA as well as at outreach locations; through visiting scientist appointments, and through workshops and conferences. The resulting effect of these

activities is expected to be the strengthening of national cowpea programs and an increased flow of improved varieties from IITA.

Extra-early maturing cowpeas (60-65 days) are being introduced into rice fallows of Asia, where the residual moisture of rice paddies is enough for a crop of 60-day cowpea varieties utilizing land on which no food crop is normally grown. These varieties have also been grown as a relay crop with rice. They provide additional farm income and add about 30 kg/ha of nitrogen into the soil for the next rice crop. By the mid 1990s, cowpeas from rice-based farming systems could amount to several million tons annually.

The extra-early (60-65 days) and early maturing (75 days) cowpeas, by virtue of their earliness also tend to escape drought and perform better than traditional varieties when intercropped with cereals. These new varieties are therefore expected rapidly to replace other varieties or crops currently used by farmers in mixed cropping systems.

The development of bush-type vegetable cowpeas which obviate the need for trellising is another source of major future impact. Lines which yield about 18 t/ha of green pods have been developed. The production of vegetable cowpeas has declined in recent years in many countries because of the excessive labor requirements. Bush-type varieties should reverse this trend.

Soybeans. Two major problems have in the past bedeviled soybean production in tropical Africa. Introduced temperate varieties have poor

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seed vigor and lose viability 3 to 6 months after harvest. These varieties, moreover, require special strains of rhizobia which are not present in tropical soils. New high yielding soybean lines with superior seed longevity and which nodulate freely with indigenous rhizobia have been developed. Together with the release of varieties adapted to high elevations and to acid soils, soybeans could be growing on 2 million ha in Africa, as compared to the present 400,000 ha, at average yields up to three times the current level, by the year 2000.

To facilitate these developments, appropriate post-harvest technologies must be developed and utilization promoted. IITA has already taken initial actions to promote small-scale and cooperative farm level processing and home utilization.

Plantains and cooking bananas. Future impact in plantains and cooking bananas will come from the newly developed tissue culture techniques for rapid multiplication of *Musa* species, the recent identification of two hormones for breaking dormancy in plantain buds, and techniques for intercropping mulch plants in plantain plantations. The tissue culture techniques will facilitate the developing and establishing plantations at lower cost. It will also provide a mechanism for distributing improved clones as well as clones resistant to diseases, such as the Black Sigatoka disease, a current threat in W. Africa.

The use of growth hormones would extend the production life of plantain plantations and increase their productivity. These growth hormones can also be used to increase the production of suckers for the

establishment of new plantations. The use of in-situ mulch is practical and has great potential to arrest the fast decline in productivity of plantain and banana plants.

Farming Systems. The generation of new scientific knowledge about soil management and conservation, as well as productive alternatives to the prevailing system of shifting cultivation has been an important step toward long-term sustainable tropical agricultural development. The technique of no-till and mulch farming for low-activity clays has been adopted in Nigeria, Thailand, Sri Lanka, Tanzania, N.E. Brazil and in Australia. The adoption and spread of soil management technologies are understandably slower than for crop varieties; the major impact of no-till and mulch farming will come in the next decade.

Another technology developed by IITA's Farming Systems Program is alley cropping. The system retains the basic features of bush fallow and constitutes an attractive alternative to shifting cultivation. On-farm trials and demonstrations of the system have recently been intensified by IITA and by ILCA (which is interested in alley cropping as a way to produce fodder for small ruminants). Alley cropping is already being adopted or tested in Costa Rica, India, Indonesia, Ivory Coast, Nigeria, Peru, Rwanda, Sri Lanka, Togo and Zaire. Because it permits continuous use of the same piece of land, alley cropping considerably reduces the need for repeated land clearing, thus enabling farmers to enlarge their holdings and increase their production and incomes. This system is expected to become an important feature of tropical agriculture by the mid 1990s.

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IITA has conducted the most detailed and authoritative studies of land clearing methods and their effects on soil properties and subsequent crop production. The recommended land clearing technology that has emerged from these studies would arrest the situation whereby forests are turned into barren unproductive land within a few years after clearing by applying inappropriate methods developed for temperate areas. IITA's recommended method is being adopted by World Bank funded projects and state government schemes in Nigeria. Much more extensive adoption is envisaged, resulting in the saving of from 2 to 4 million ha of land annually by the mid 1990s.

A key activity of the Farming Systems Program is the development of appropriate machinery for farmers with small and medium holdings. The rolling injection planter, a cassava lifter and a low horsepower multipurpose machine for zero or minimum tillage use have all been developed and should see more widespread use over the next decade.

A new thrust of the Socio-Economics Unit of the Farming Systems Program is the role of women in agriculture. This project will identify the particular technological needs of women, indicate ways of getting their inputs into the formulation of research and development priorities, increase the extent and pace of agricultural technology adoption, and will help to promote social justice.

19.2.8 Future impact of research at ICARDA

Since its inception in 1977, ICARDA has been working on breeding improved cultivars and developing appropriate management techniques for the dry areas of W. Asia and N. Africa. In these dry and variable environments, the gestation period involved in breeding, testing, release, seed production and distribution of new cultivars is longer as compared to more stable environments.

Results stemming from ICARDA research are beginning to appear and potential impact in the future appears to be substantial. Even with conservative projections, expected benefits are high. To gauge the future impact, ICARDA research is grouped into three main areas: Cereals, Food Legumes; and Pasture, Forage and Livestock Improvement.

Cereal Research. The estimates of future benefits for cereals and food legumes are based on the following assumptions: (a) The current annual level of funding in real terms ($8m) will allow maintenance research to continue. (b) Potential yield increases are observed by comparing the results of several years of multi-location farmers' fields verification trials and actual average yields in W. Asia and N. Africa. (c) Only 50 percent of this potential increase will be realized by the year 2000 and 50 percent of the realized benefits will go for increased costs. (d) The benefits pertain to rainfed agriculture except for the Nile Valley Project, i.e., benefits from yield increases due to spillovers to irrigated agriculture are ignored. (e) These benefits will

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occur between 2000 and 2010. In general, gradual benefits should be accruing prior to 2000 but these are ignored.

The yield potential of wheat is over 2.6 t/ha vs actual current yields of 1.44 t/ha in W. Asia and N. Africa. For barley, the yield potential is 2.1 t/ha vs actual current barley yields of 1.16 t/ha in W. Asia and N. Africa.

Using prices of $100/t for wheat and $75/t for barley, according to these assumptions, the benefits of cereal research will amount to $1.1 billion a year in W. Asia and N. Africa between 2000-2010. This is distributed as $0.9 billion for wheat and $0.2 billion for barley. These benefits refer only to grain and do not take into consideration increased straw and grazing benefits. The increases in sheep and dairy products as a result of increases in barley production are not accounted for here. Further increases are possible with research on increased and more efficient moisture use, higher stress tolerance and increased and more efficient use of fertilizers.

Barley is grown in the drier areas of the region where it has a comparative advantage due to its lower moisture requirements. However, in the drier areas, virtually no fertilizer is used in barley production. The Farming Systems Program identified fertilizer use on barley as a means to enhance productivity and stability. Phosphorus use increases water use efficiency by allowing higher dry matter production per unit of moisture; enhances maturity by 1-2 weeks; increases average yields by over 50 percent and is profitable in most years in typical

barley growing areas. These results are expected to lead to a re-evaluation of fertilizer policies for the direr areas by national programs. While the potential effect of this research is not evaluated separately, it can be considered as complementing the potential impact of commodity research.

Food Legumes Research. Future impact will stem from the development of cultivars and practices for the winter planting of chickpeas. Chickpeas are an important part of the diet in W. Asia and N. Africa and are a good source of protein. In this region, chickpeas are grown mainly in the spring. The experience from verification trials in Syria indicates that yields over 2 t/ha are possible. The potential to double the current yields of 600 kg/ha in W. Asia and N. Africa should be realized within ten years.

Winter chickpea research is allocated less than 6 percent of the Food Legume's budget, i.e., less that $0.5m. Using a price of $250/t the benefits from winter planting chickpeas in W. Asia and N. Africa are expected to be around $60m a year between 2000 and 2010. However, several problems need further research in winter planting of chickpeas. These relate to cold tolerance, Ascochyta blight, Orobanche control, mechanization of harvesting and labor requirements for weeding.

Pasture, Forage and Livestock Research. Around 70 percent of this research is directed toward increasing the use of fallow land for pasture and forages. The potential impact of replacing fallow with higher productivity pastures and forages can be stated succinctly as: 80 Mt of

herbage on 20 million ha, which can support 100 million ewes, and fix 60 kg/ha of nitrogen, amounting to 1.2 Mt of nitrogen, and, most importantly, increase productivity and cropping intensity, and perhaps reduce the pressure of cultivation and grazing on marginal and fragile lands.

Taking into account the increases in fallow productivity and the consequent increase in livestock production, increased costs of production, but ignoring the effects on cereal production through nitrogen fixation and the effects of reduced pressure on marginal lands, maintenance of research at the current level ($4.3m) should result in net benefits of over $1 billion (and possibly as high as $2 billion) a year to accrue between 2000 and 2010.

It should be stressed that considerable further research and action than that indicated for ICARDA needs to be undertaken, particularly at the national level. Allocation of more resources to research and extension, seed production, agricultural infrastructure, storage and agricultural policy, is needed if the potential impacts are to be realized.

19.2.9 Future impact of research at ILCA

Pastoral development is constrained by many factors. As a consequence an integrated approach for the generation and diffusion of new knowledge has been adopted. Due to the nature of the problems and the approach taken, the future impact of ILCA will come from enhanced

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knowledge of African livestock systems rather than, say, the developing of higher yielding crop species.

Of particular note are the future returns from ILCA's investment in information and documentation services. Many of Africa's researchers, educators, planners and policy makers have difficulty in getting ready access to timely information. ILCA's service of selective information dissemination is now providing 400 key livestock personnel with rapid access to reading data bases. This will have a broadly based return in training, university education, research and policy formulation. The linking of individuals and institutions through various networks (for byproducts, for trypanotolerance research, animal traction, livestock policy and legume forages) will serve to strengthen the exchange of information.

The following are the major specific areas in which ILCA's future impact will lie.

Legume-foodgrain-livestock systems. Currently, livestock and food grain production are closely associated in many African farming systems. The introduction of forage legumes could greatly increase both crop and livestock output. Systems such as alley cropping, intercropping and legume-crop rotations are being explored. Most soils are deficient in nitrogen and phosphorous and, as applying nitrogen is rarely feasible, the use of small amounts of phosphoric fertilizer can stimulate legume growth for biological fixation. This would raise subsequent crop yields, while the greater availability of leguminous forage would add to the

intake and utilization of other forages. For example, in the subhumid zone of Nigeria the use of up to 4 ha of Stylosanthes spp. for dry-season feeding raises animal production and has lead to a doubling of maize yields using the residual nitrogen.

Dairy production. Introduction of cross-bred dairy cows and leguminous forages can raise annual milk yields and farm cash incomes very substantially. Cooperative work with national programs is leading to the design of smallholder dairy projects.

Animal traction. ILCA's work is leading to the formation of a regional network to assist national efforts in training, research and documentation. Modifications to harnesses and implements has shown that single oxen can be effectively used for cultivation. This should significantly increase the proportion of smallholders who can use animal power for crop production.

ILCA's animal traction research will increasingly focus on animal nutrition, especially the more efficient use of low-quality crop byproducts, the feeding value of which can be enhanced by the strategic use of molasses and urea mixtures. Major revisions of African smallholder feeding systems for draught animals, dairy cattle and small ruminants are expected to result from the research.

Pastoral assessment. ILCA is developing a capacity to appraise African pastoral and agricultural resources through the use of high resolution satellite imagery in collaboration with NASA in the USA.

Research in progress to calibrate ground data with satellite information will enable within-season crop and pasture performances to be estimated. This will facilitate rapid national-program responses to current environmental conditions.

19.2.10 Future impact of research at IFPRI

As indicated in chapters 11 and 12, two major types of output of the centers are improved research capacity of the national research systems and improved agricultural policy in developing countries.

As IFPRI, whose primary responsibility is for policy research, is relatively new to the system, much of its impact is necessarily in the future. There are almost no studies which quantify either the past or future benefits of policy research or improving research institutions.

The outputs of the centers in this area are intermediate products which go into the policy making or research system along with many other inputs, and eventually produce a new policy or technology. The affects of the technology or policy on farmers' and consumers' incomes is the ultimate measure of benefits. However, the problem of attributing a specific change in income to the centers is far more tenuous than tracing a new variety to the centers. Despite these problems, the CGIAR, center directors and national policy makers are faced with the problem of deciding how much money should be invested in developing new genetic material as opposed to research on agricultural policy or research on

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agricultural research. It would therefore, be useful to show the possible size of the payoffs.

There are a number of policies which are forthcoming based on collaborative research between IFPRI and national researchers. Five are chosen to illustrate different types of impact.

The collaborative work of IFPRI researchers with the Egyptian government on food subsidies is described in chapter 12. On the basis of that research, the government is trying to initiate a number of policies which will make the Egyptian system of food policies less costly, and more efficient in meeting its goal of inexpensive food for the poor. The first of these policies are already in place: subsidies were decreased by phasing out the subsidy on frozen products and by restructuring the system of ration distribution for upper income groups. Other policies are under discussion.

The shift in irrigation investment policy in the Philippines from large-scale reservoir systems to smaller-scale systems is just starting to have its impact on new investments. It seems likely that similar changes in the irrigation policies of Indonesia can be expected.

Cost-effective ways of planning and sequencing rural infrastructure and designing infrastructure so that the poor will have access to it have been incorporated in the long-range plans in Andhra Pradesh. The same process of collaborative research on infrastructure is being carried out in Tamil Nadu, Zimbabwe and Zambia. It seems highly likely that the

results in these states and countries will also be more effective infrastructural investments.

Detailed studies of growth linkages in Malaysia and Nigeria have been completed and studies are being completed in India. These studies will lead to policy changes on priorities for rural infrastructure investments, access to markets and services, policies toward small businesses and targeting of new technologies in Malaysia, Nigeria and India.

IFPRI's research on African agricultural research systems is likely to lead to changes in research resource allocation and in the projects which donors choose to fund. IFPRI's research is part of a World Bank project and, as such, will have direct access to the Bank, a major donor, and to the governments themselves, enhancing the likelihood that recommendations may be adopted.

19.2.11 Future impact of research at ISNAR

ISNAR has collaborated with a number of national research programs with a view to changing institutions or policies. The recommendations of their review missions tended to fall into three main categories: (a) changes in the structure or functioning of the system for more effective utilization of available or potential resources; (b) determining and developing the necessary human resources for agricultural research; and (c) strengthening the system's external linkages. In 12 of the 18 countries where review missions have worked, institutional and

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organizational changes were recommended. Because it was formed so recently, most of the impact of ISNAR is still in the "pipeline". Many of the institutional changes that have been proposed were accepted but most of them are still in the process of being implemented.

In the case of the Dominican Republic, ISNAR has made a major input into the process of identifying the problems, helping to develop new proposals, and then convincing legislators of the need for the institutional change. The change has recently been approved, and USAID is planning a project to fund a new research institution. This will be one of the first cases of an accomplished institutional change assisted by ISNAR.

19.3 Future Benefits: Selected Cases

The following analyses of selected cases is aimed at capturing the principal characteristics of investment in research. These are:

(a) There is a lag between when a project is initiated and when any results are first applied;

(b) Adoption of a new technology takes time, as farmers learn and experiment;

(c) Most biological technologies require continued investment to maintain their productivity;

(d) Expenditures by the centers are only one part of the total investment needed to produce and extend a new technology; and

(e) Future uncertainties make the payoff to investment in research uncertain.

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A diagramatic view of the analysis used to estimate the future payoffs is shown in Figure 20.1. Competing demands for the study resources made it impossible to deal explicitly with future uncertainties. Rather, the approach taken was to use assumptions that are overly cautious so that the results are conservative estimates. The results can be viewed as lower bounds on the possible outcomes. In fact, such an exercise is more useful for ranking projects than for determining the absolute payoff to any one project.

The selection of cases is intended to be illustrative rather than fully representative. Cases are included only where sufficient information was available to speculate about possible future benefits. A partial listing will tend to exclude many projects with more limited prospects for success so that this approach does not provide insights to the overall return to the system. It also excludes projects whose nature is such that their inputs and outputs are not readily fitted into the framework shown in Figure 19.1.

19.3.1 Upland rice in Latin America

Collaborative efforts between the centers and national researchers have led to substantial increases in rice output in Latin America. However, in large part, these gains were confined to the irrigated sector. Further scope for increasing the output in this sector is limited.

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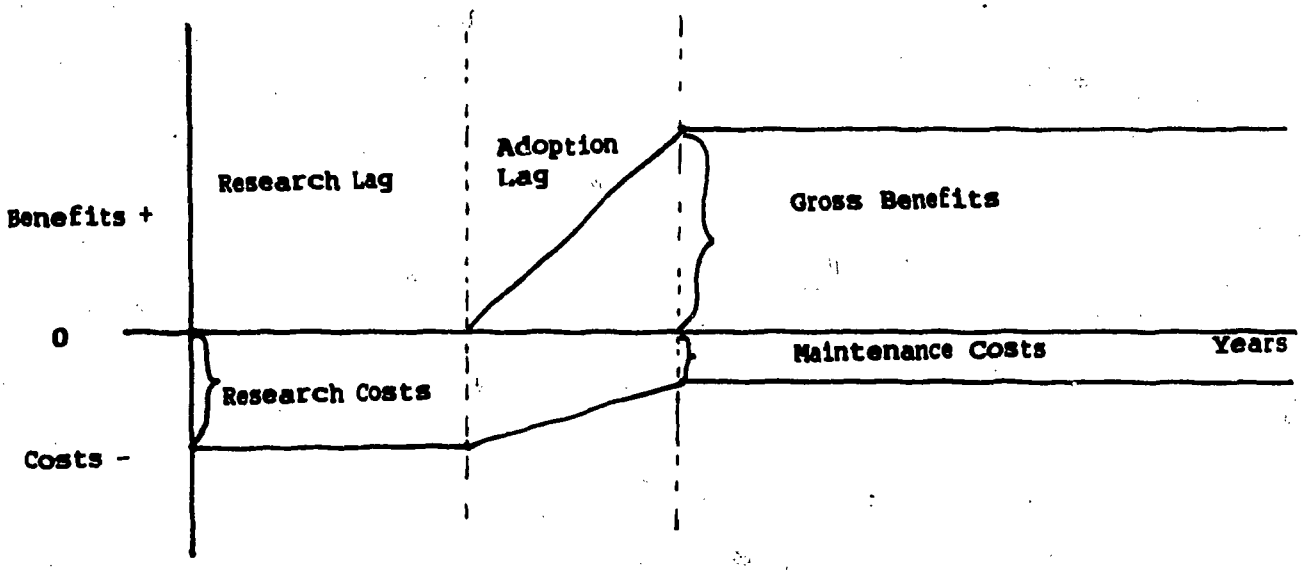
Figure 19.1 A Model of the Returns to Research



where

Gross benefits = (Area)x(Change in yield)x(Price)

Area = (Maximum area) x (Proportion to which the technology is applicable)

Change in yield = (Maximum expected increase in yield) x (Proportion attributed to investment in centers)

Price = (Farmers price per ton) x (Proportion remaining after meeting additional input costs associated with implementing the technology)

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As a consequence, increased attention has been given to upland systems, especially in the more favored regions of Mexico, Costa Rica, Guatemala, Venezuela, Colombia, Ecuador, Peru and Brazil. Vast areas of these infertile oxisols, while receiving adequate rainfall, suffer from high aluminum concentration. Upland rice with yields of 2 to 3.5 t/ha could be grown on up to 2.1 million ha of this land with tolerant varieties incorporating disease resistance.

19.3.2 Biological control of cassava pests

Joint efforts by CIAT and IITA are aimed at developing biological control of green spider mites and mealybugs. These pests have spread rapidly and threaten much of the cassava areas of Africa and parts of Latin America. Resistant cultivars, clean seed and pesticides are all possible strategies for control, but the use of natural predators seems to be a promising approach.

An Africa-wide project has been proposed and initiated and the estimates of the research costs are drawn from this project together with allowances for research at IITA and CIAT and in the national programs. Yield losses from these pests are estimated to be 30 percent on average at present. This project is the largest biological control scheme even attempted, and there are still biological, technical and logistic problems to be resolved. At present, prospects are better for mealybug control than for green spider mite.

19.3.3 Tolerance to aluminum in wheat

Since 1974, CIMMYT has been collaborating with three Brazilian centers to develop wheats tolerant to aluminum toxicity. Semi-dwarf varieties are sought which incorporate high yield, with rust and Septoria resistance. Cultivars are at present available and steady progress is being made through a shuttle breeding system between Mexico and Brazil combined with rapid screening in the laboratory. Some advanced lines have been found to use phosphorus very efficiently, an important attribute for acid soils that are commonly low in available phosphorus.

19.3.4 Heat tolerance in wheat

A number of countries with humid tropical environments are seeking to grow wheat during their coolest season. Of particular importance has been the development of resistance to disease due to Helminthosporium and Fusarium spp. Selections from spring-winter crosses are being made to find materials with greater tillering ability under high temperatures. Within three to five years, varieties should be available for Brazil, N. Argentina, Sudan, parts of India, Pakistan and Bangladesh. These are expected to raise yields 15-20 percent in years of high heat, or on average by 100 kg/ha. It is recognized that yields equal to those of subtemperate zones cannot be attained.

19.3.5 Resistance to downy mildew in maize

Downy mildew is a major disease of maize found in S. and S.E. Asia, but is increasingly prevalent in Africa and Latin America. A recurrent selection approach was developed with Thailand and the Philippines. Disease resistant plants were selected in these countries, and recombined and further selected for desirable agronomic features in Mexico in the following season. By 1980 after four such cycles, a trial of 12 resistant varieties was sent to 18 countries where, under severe infection, the new varieties yielded 14 to 81 percent higher than the best checks. Within three years, materials with an average 10 percent yield superiority should be available for 80 percent of the crop in India and the Philippines, and 30 percent in Thailand, Vietnam and S. China. By the early 1990s, CIMMYT expects to have varieties suitable for 5 million ha of humid African lowlands, and for about one quarter of the area in Mexico, Guatemala, Peru, Venezuela and Ecuador.

19.3.6 True potato seed

Research on true potato seed was started by CIP in 1977 and now involves collaborative research in 34 countries, on-farm evaluations in seven countries and commercial use in four countries. It offers several potential advantages over seed tubers:

(a) The cost of seed can be markedly reduced. These savings can represent up to 50 percent of total production costs;

(b) Additional tubers would be available for consumption. At present 14 percent of output in developing countries is used as seed;

(c) Disease spread would be reduced;

(d) True seed would be available for planting at any time allowing more flexibility to fit potatoes into cropping patterns.

The technology is likely to be more suitable to areas where land is relatively scarce and labor relatively abundant as it allows more consumer potatoes to be produced per hectare but requires up to twice the labor of crops grown from seed tubers. Estimates of the potential area are based on the Near and Far East and China. The savings in unit costs (assumed to be 20 percent) were expressed as an equivalent yield increase of 12 percent from a present average of 12 t/ha in these areas.

19.3.7 Summary of the data

Table 19.3 summarizes the data used in calculating the returns to research in these cases. In general, the following conservative assumption have been made:

(a) Only 80 percent of the maximum stated area was taken as the potentially applicable area for the technology'

(b) The adoption lag was assumed to be 10 years (five years in the case of biological control);

(c) The research costs include both the centers' expenditures, together with allowances of at least an equal amount for those of national programs;

(d) Only 20 percent of the expected yield gains were attributed to investment by the centers; the remainder was assumed to be due to the

TABLE 19.3 Summary of Data Used to Calculate the Return to Research

Variable	Units	1.	2.	3.	4.	5.	6.
Maximum potential area	mill. ha	1.7	6.1	4	5	10	4.6
Adoption lag	years	10	5	10	10	10	10
Research costs	$m	5	10	4	4	3	5
Research lag	years	5	3	3	5	10	10
Proportion of research costs needed as maintenance research	-	0.4	0.4	0.4	0.4	0.4	0.4
Increase in yield	kg/ha	300	400	150	100	60	290
Price	$/t	250	30	150	150	100	100
Proportion of increased returns net of extra inputs	-	0.25	0.67	0.4	0.4	0.4	1.0

1. Rice for favored upland areas of Latin America
2. Biological control of cassava pests
3. Tolerance to aluminum in wheat
4. Heat tolerance in wheat
5. Resistance to downy mildew in maize
6. Use of true potato seed.

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effort of national research and extension programs, and investment in rural infrastructure and in human capital;

(e) After the critical investment period it was assumed that maintenance research would be needed at a level of 40 percent of the initial annual costs; and

(f) All projects had a total life of 35 years. Beyond that it was assumed the technology had no further benefits.

There is an inevitable element of arbitrariness in these assumptions. The uniform application to all projects introduces a potential bias in the ranking. For example, assuming that only 20 percent of the expected yield gains are attributable to efforts by the centers may be reasonable for certain commodities in countries with strong national programs. In other cases, it is possible that the contribution by a center is very much higher. A small country with a weak national program may depend very heavily on the receipt of finished genetic material, training and scientific support from a center, in which case a much larger share of any realized increases in output might justifiably be attributed to that center. Such problems, however, reflect deficiencies in the data rather than necessarily in the framework. It merely serves to highlight the shortcomings in the existing level of investment analyses undertaken by the centers.

19.4 Results and Conclusions

Table 19.4 summarizes the results for the six cases. There is no single index of net returns that is universally useful or accepted. The

Table 19.4 Future payoffs to selected technologies

Example	Present value of future net benefits discounted at 10% p.a.	Internal rate of return	Benefit/ cost ratio
1. Rice for favored upland areas of Latin America	84	25	3.3
2. Biological control of cassava pests	220	41	4.5
3. Tolerance to aluminum in wheat	140	45	6.2
4. Heat tolerance in wheat	86	28	4.0
5. Resistance to downy mildew	32	17	2.3
6. Use of true potato seed	274	28	7.6

table presents (a) the present value of future net benefits, (b) the internal rate of return, and (c) the benefit/cost ratios. The present value is found by discounting the difference between gross benefits and costs in each year at a conservatively high rate of 10 percent a year.

Each of the technologies was evaluated under basically similar assumptions. All three measures of performance show wide variation. Given the uncertainties inherent in the analysis it is useful to examine the sensitivity of the results. For example, if the research lag for upland rice was 10 years instead of five, the net return would fall to $16m and 14 percent, with a benefit/cost ratio of 1.4. In contrast, if the yield gain for heat tolerance in wheat were 30 rather than 100 kg/ha, the return would fall to $5m or an internal rate of return of 11.8 percent.

The CGIAR system is investing of the order of $200m annually, yet little if any systematic attempt is made to assess the likely return to this investment. Without such analysis, there is no guarantee that the marginal returns to different projects within the system bear any relation to one another. It is possible that the expected returns in one area or commodity exceed those in another by significant amounts under all possible future outcomes. The scarcity of research resources demands that the maximum gains be extracted from any given budget. This can only be done if investment alternatives are viewed in terms of their expected payoffs.

Clearly, a measure of economic efficiency cannot be the only criterion for allocating research effort. Concerns may arise from the need to develop certain regions, for nutritional needs, or for the distribution of income among classes of producers, between consumers and producers, for returns to labor, etc. It does not follow that imposing these criteria necessarily implies accepting a lower economic return. But the objectives need to be explicit, so that the relative merits of research in comparison to other policies can be gauged. Redirecting research efforts to, say, an environmentally harsh setting in order to generate income gains for a poor community might entail considerable cost in terms of output foregone in another region. A clearer appreciation of these trade-offs would presumably lead to more informed judgements about the allocation of research effort.

Attempts to direct additional funding into such areas may result in a very much lower return than those marginal resources might have generated elsewhere. Poor subsequent performance of the research system may then jeopardize future funding.

It is, therefore, inescapable that the system continually review the future expected benefits with a view to making those adjustments which will lead to a higher overall payoff to research. A first step is to estimate the added value of output due to research across a number of producing systems. This will identify those areas where the total contribution of research is likely to be small. The efforts of IRRI are a valuable example of this step. But a more adequate treatment must involve estimating the additional returns to research at different

levels, so that the marginal, rather than just the average returns can be equated across the different systems. For example, IRRI estimates that the annual value of extra rice from irrigated regions in S. and S.E. Asia until the year 2000 could be $10 billion, while from floating systems it could be $380m. At first glance, this appears to provide an allocation rule in which about $40 should be spent on irrigated research for every $1 on floating rice research. But the marginal return on research on floating rice could be many times greater (or less) than that in irrigated culture. Without more attention to estimating the changes in output with respect to different levels of research, little can be said about the efficient use of limited rice research funds. Of course, the same is true of research allocation in other centers.

History has shown that, on average, the returns to research have been high. But more attention must be given to future impacts if these rates of return are to be maintained. Choices about investment in projects must be based on measures of their expected contribution rather than on the general notion that past research has been worthwhile.

Any statement of future impact must recognize that still too little is known about the impact of expanded food production on marginal and fragile lands. Continued monitoring will be needed to ensure that the environmental consequences are adequately reflected in the design of technology for modern agriculture with its dependence on fertilizer and water, and its narrower genetic base. While there are some analyses of these questions, many of the issues are still untested hypotheses.

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The future returns will depend in part on close and effective collaboration with national programs. As those future returns are sensitive to the area of the crop, large countries loom especially important. The centers will not be able to afford simply to withdraw from those large countries with advanced self-sustaining research systems. Concentrating on strengthening small weak programs may risk diverting the centers' attention from the extensive areas from where their greatest contribution must continue to come.

19.5 Coda

* Past investment in research has generally yielded high dividends. This experience, drawn from many regions various periods and for a variety of commodities is at the very least a reassuring guide to possible future returns.

* The international research system has grown in coverage and complexity raising the possibility that future returns cannot be expected to be so high.

* In wheat and rice, gains from the stock of knowledge existing prior to the centers' formation arguably contributed to early successes. Such stocks were notably lacking for many other crops, and a much greater proportion of their output comes from less favorable environments. Some would argue that nature becomes successively more niggardly in yielding secrets. For these reasons, it is pertinent to consider future impacts.

* Any diminution in the perceived return to research could dampen the enthusiasm of support by donors; likewise any tendency to create unrealistic expectations should be avoided.

* Inevitably, the estimation of future impacts is fraught with pitfalls. Understanding of the processes of generation and international diffusion of technological change is most imperfect. The mere presentation of quantitative estimates of future net benefits creates an aura of precision which may not be justified.

* Research resources both for national and international research are always limiting. There are inevitably more opportunities for additional research than funds to match. Decisions about their allocation must be made - and are, in fact, made every day by donors, by research directors, and by scientists within specific projects.

* Estimates of possible future benefits provide one extra element to be used in reading those judgements. They cannot supplant the informed insight, experience and accumulated knowledge that have always formed the cornerstone of decisions about internationally funded research. At best, they can help in the ranking of projects, they can indicate where shifts in emphasis might raise total returns and they can signal projects whose expected payoff would be so low as to be quite unattractive.

* A wide range of forthcoming results from the centers has been reviewed. They indicate that, potentially, there are still some very

substantial gains to be made. This is particularly true of widely adapted technologies relevant to large areas.

* In almost every centre, success during the next decade in just one major project would generate returns far in excess of the cost of the centre. In some cases, success in one project would generate benefits greater than the present costs of the entire CGIAR system.

* Six specific projects examined yielded expected annual rates of return of between 20 and 40 percent, even with a small share of very modest gains in productivity attributed to the investment by the centers.

* The fact that the work of all centers has applicability over wide areas almost predetermines a high rate of return to even small increases in productivity. This will mean, however, that the return in a particular country may not be very high if the volume of production is small and the national program needs extensive supporting.

* Neither the centers nor the system acting collectively have invested much effort in attempting to assess the return to an annual investment of $200m. There can be few other institutions either public or private who devote such a small share of their portfolio to providing the best possible information about the expected return to investment.

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Appendix Table 19.1 Estimated value of gains from rice research leading to increased rice production (area, yield of rough rice, croping intensity) in South and Southeast Asia to year 2000).

	Rice Culture Type (000 ha):		Irrigated		Rainfed				
		Units	1 Crop	2 Crop	Shallow	Interme-diate	Very Deep	Dryland	Total
PRESENT (1980)	Harvested area	(000 ha)	13641	15226	30375	11587	5290	11593	87712
	Rice yield	(t/ha)	3	3.5	1.8	1.4	1	1	
	Production	(Mt)	40.92	53.29	54.68	16.22	5.29	11.59	182
	U crop (yield in 2000)	(t/ha)	.5	.5	.3	.3	.3	.2	
	Crop intensity, rice		.9	1.8	.9	.7	.7	.8	
	Crop intensity U crop		.3	.2	.4	.3	.3	.5	
	Geographic area	(000 ha)	15157	8459	33750	16553	7557	14491	95967
AT 2000	Irrigated increase(1.5%)	(000 ha)	4731	5281	-4946	-1887	0	0	3180
	Wetland check	(000 ha)	20414	11393	28255	13857	7557	14491	95967
	Rainfed increse	(000 ha)	0	0	4500	500	0	1200	6200
	Harvested area	(000 ha)	18372	20507	29929	10200	5290	12793	97092
	Geographic area	(000 ha)	20414	11393	33255	14572	7557	15991	103181
	Change rice yield		1.2	.9	.8	.8	.5	.5	
	Change rice intensity		.4	.5	.3	.2	.1	0	
	Change U crop intesity		.2	.2	.1	0	.1	.3	
	Rice price	($/ton)	100	100	100	100	100	100	
	U crop price	($/ton)	150	150	150	150	150	150	
Change due to Irrigation	Rice (no research)	($m)	1419.37	1848.35	-890.226	-264.169	0	0	2113
	U crop (no research)	($m)	118.28	44.01	-98.91	-36.39	0.00	0.00	27
RICE Research (no intensity)	Rice-old area	($m)	1636.92	1370.34	2430.00	926.96	264.5	579.65	7208
	Rice-new area	($m)	567.75	475.2887	-35.66	-110.95	0.00	60.00	956
	Rice total	($m)	2204.67	1845.629	2394.34	816.01	264.5	639.65	8165
INTENSITY effect	Rice area change	(000 ha)	8165.44	5696.38	9976.43	2914.31	755.71	0.00	27508
	U crop area change	(000 ha)	4082.72	2278.55	3325.48	0.00	755.71	4797.38	15240
Old Technology:	Value Rice, OT	($m)	2449.63	1993.735	1795.76	408.00	75.57	0.00	6723
	Value U crop	($m)	306.20	170.89	149.65	0.00	34.01	143.92	805
New Technology:	Value Int*Tech	($m)	979.85	512.67	798.11	233.14	37.79	0.00	2562
VALUE RESEARCH+IRRIGATION+INTENSIFICATION		($m)	6059	4567	5039	1421	412	784	18281
		(%)	33	25	27	8	2	4	100
Added Paddy Production 1980-2000		(Mt)	56.34	43.52	49.88	14.57	3.78	6.40	174
Added value of rice from research		($m)	5634	4352	4988	1457	378	640	17449
		(%)	32	25	29	8	2	4	100
Added value of upland crops		($m)	424	215	51	-36	34	144	832
Irrigation effect, no research		($m)	1538	1892	-989	-301	0	0	2140
Paddy rice production at 2000		(Mt)	97.26	96.81	104.56	30.79	9.07	17.99	356
Annual compound growth rate		(%)	4.42	3.03	3.29	3.26	2.73	2.22	3.42

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Appendix Table 19.2 Estimated cost savings from research leading to increased fertilizer and pest management efficiency on rice in South and Southeast at the year 2000.

			Rice Culture Type (000 ha)						
			Irrigated		Rainfed				
		Units	1 Crop	2 Crop	Shallow	Deepwater	Floating	Dryland	Total
PRESENT (1980)	Harvested area	(000 ha)	13641	15226	30375	11587	5290	11593	87712
	Crop intensity, rice		.9	1.8	.9	.7	.7	.8	
	Crop intensity U crop		.3	.2	.4	.3	.3	.5	
	Geographic area	(000 ha)	15157	8459	33750	16553	7557	14491	95967
	N-fertilizer	(kg/ha)	50	65	30	5	5	5	
	Urea check	(000 t)	682.05	989.69	911.25	57.935	26.45	57.965	2725
	Insecticide use	($/ha)	10	10	6	2	1	1	
AT 2000	Irrigated increase(1.5%)	(000 ha)	4731	5281	-4946	-1887	0	0	3180
	Wetland check	(000 ha)	20414	11393	28255	13857	7557	14491	95967
	Rainfed increse	(000 ha)	0	0	4500	500	0	1200	6200
	Harvested area	(000 ha)	18372	20507	29929	10200	5290	12793	97092
	Geographic area	(000 ha)	20414	11393	33255	14572	7557	15991	103181
	Change rice intensity		.4	.5	.3	.2	.1	0	
Fertilizer use	No research	(kg/ha)	132.66	172.46	79.60	13.27	13.27	13.27	
Insecticide use	No research	($/ha)	21.91	21.91	13.15	4.38	2.19	2.19	
Fertilizer use,	no intensity effect	(000 t)	2437.34	3536.70	2382.32	135.32	70.18	169.72	8732
Fertilizer use,	intensity effect	(000 t)	974.93	1768.35	714.70	27.06	7.02	0.00	3492
Fertilizer use,	total, 30% efficiency	(000 t)	3412.27	5305.05	3097.02	162.38	77.20	169.72	12224
Fertilizer use,	total, 40% efficiency	(000 t)	2559.20	3978.79	2322.77	121.79	57.90	127.29	9168
Fertilizer saving		(000 t)	853.07	1326.26	774.26	40.60	19.30	42.43	3056
Value N-saving		($m)	127.96	198.94	116.14	6.09	2.89	6.36	458
		(%)	27.92	43.40	25.34	1.33	0.63	1.39	100
Insecticide use,	no intensity effect	($m)	402.56	449.33	393.47	44.70	11.59	28.03	1330
Insecticide use,	intensity effect	($m)	161.02	224.67	118.04	8.94	1.16	0.00	514
Total insecticide,	No IPM	($m)	563.58	674.00	511.51	53.64	12.75	28.03	1844
Insecticide use,	with IPM	($m)	281.79	337.00	255.76	26.82	6.38	14.02	922
Value Insecticide saved		($m)	282	337	256	27	6	14	922
		(%)	31	37	28	3	1	2	100
Efficiency Savings		($m)	410	536	372	33	9	20	1380
		(%)	30	39	27	2	1	1	100

See Appendix 1 and 2 for assumptions contained in Table 2.

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Appendix Table 19.3 Selected new bean technologies soon to be available at farm level.

Characteristic	Approximate Date of Availability	Estimated Yield Gain	Probability of Attainment	Potential Area of Impact ('000 ha.)	Region of Impact
Earliness	86	Reduced instability by drought avoidance and area increase through increased cropping intensity	Very high	1200	Central America, N.E. Brazil, Kenya, Middle East Peru; Mexican Highlands.
Integrated Web Blight Control	86	30-50% + area expansion	Medium to high	300	Warm humid parts of Brazil Central America, Argentina
Refined Target Area/Problem Diagnosis through On-Farm Trials, Economic Surveys and Agro-ecology Studies.	86	Gradual increase	High	860	Short term in Rwanda, Burundi, Colombia, Ecuador Argentina, Costa Rica.
Improved Local Adaption of Materials Through Decentralized Selection to National Programs Supported by Training.	87-88	20%	High	4500	Mexico, Cuba, Turkey, E. Africa, Brazil, Central America.
Ashy Stem Blight Resistance	87	30%	High	600	Middle East, N.E. Brazil.
Lateness	87	50%	Medium to high	400	Moderately favored or irrigated areas in Mexico, Brazil, Middle East, Argentina.
Disease Resistance through Inter specific Hybridization					
a) Bacterial Blight	87	10%	High	700	Tropical Brazil, Mexico, Argentina, Central America
b) Ascochyta Leaf Spot	90	10%	Medium	80	Highland Guatemala, Peru, Ecuador, Colombia.

Appendix Table 19.3 (cont.)

Characteristic	Approximate Date of Availability	Estimated Yield Gain	Probability of Attainment	Potential Area of Impact ('000 ha.)	Region of Impact
Drought Tolerance	87-88	Increased stability and up to 10% average yield increase	Medium	500	Kenya, Mexican Highlands Middle East.
Nitrogen Fixation	88-89	15% plus fertilizer savings	Reasonable chance	250	Africa. Some areas in Mexico.
Bean Fly Resistance	88-89	10-15%	Medium	500	Drier bean areas of Africa
Tolerance to Low-Fertility Soils	90	15%	Medium	2500	Brazil, Africa
Plant Architecture and Yield Potential	92-95	25-30%	Reasonable chance	350	Coastal Mexico and Peru, Turkey, irrigated Brazil, Argentina.

Appendix Table 19.4 Pipeline developments in cassava research.

A: Germplasm	Description of production problems	Region of expected impact (See columns V, VI)	Expected yield increase through improved germplasm (t/ha/year)	Time lag until major varietal improved germplasm (t/ha/year)	Probability of acceptance of new varieties
Edaphoclimatic zone 1 (lowland tropics with long dry season, low to moderate rainfall high temperature year-round)	Drought, mites, thrips, mealybugs, termites, bacteriosis, root rots, viruses	Atlantic Coast of Colombia N.E. Brazil Thailand Panama India	5-10 t/ha	0-5 years	Good
Edaphoclimatic zone 2 (acid soil savannas with moderate to long dry season, low relative humidity during dry season)	Low soil fertility, drought, bacteriosis, superelongation, anthracnose, Cercospora leafspot, mites, mealybugs, lacebugs	Plains of Colombia and Venezuela Cerrados of Brazil Savannas of S.E. Mexico	5-10 t/ha	0-6 years	Good
Edaphoclimatic zone 3 (lowland tropics with no pronounced dry season, high rainfall, constant relative high humidity)	Low soil fertility, root rot, Cercospora leafspot superelongation, anthracnose	Tropical rainforest areas of Latin America Hot humid lowlands of Africa (IITA-lines with CIAT germplasm-input) Philippines Indonesia	10+ t/ha	0-8 years	Good in the Philippines; moderate in other countries
Edaphoclimatic zone 4 (medium altitude (800-1500 m) tropics with moderate temperature and rainfall)	Thrips, mites, mealybugs, bacteriosis, mycoplasma, anthracnose, root rots, viruses	Medium altitude Andean zone of Latin America Kenya, Cameroon (IITA lines with CIAT germplasm input) Sri Lanka, India	8-15 t/ha	0-5 years	Moderate in Africa and Asia; excellent in Latin America
Edaphoclimatic zone 5 (cool tropical highland (1600-2200 m) with mean temperatures of 17-20°C)	Low temperature, Phoma leafspot, anthracnose, mites, long growing cycle	Medium to high altitude Andean zone of Latin America, Kenya, Rwanda, Burundi, Cameroon (IITA-lines with CIAT germplasm input)	4-8 t/ha	4-6 years	Moderate
Edaphoclimatic zone 6 (subtropical areas with cool winters and fluctuating day length)	Low winter temperature bacteriosis, anthracnose, superelongation, photo-period	Southern Brazil and Paraguay Mexico, Cuba and the Caribbean N.E. India, China	8-12 t/ha	7 years	Excellent

Appendix Table 19.4 (cont.)

B. Cultural practices	Description of problems to be attacked	Region of Impact	Expected yield increase through cultural practices	Time lag until commercially acceptable	Change of adoption
Biological control methods predators parasites and pathogens	Mites, mealybugs, hornworm, root rots	Africa N.E. Brazil Andean zone of Latin America	Yield losses estimated at 30-40% of present production levels	Now being adopted	Moderate in Latin America Good in Africa
Estimated practices	Cyrtomenus bergi root rot, erosion problems, fertility maintenance	Africa Latin America Asia	Up to 60% commercial yield losses to be avoided	Now being adopted	Moderate
Mycorrhiza cultures	Low phosphorus levels in soil	Plains of Colombia and Venezuela Cerrados of Brazil Tropical rain-forest areas S.E. Asia Parts of Andean zone	± 30%	5-7 years	Poor
Stake selection and treatment	Low germination, early disease and insect incidence, harvest to planting time lags	Everywhere	± 70%	Now being used	Good
Improved intercropping	Disease/pest incidence, soil fertility, risk spreading	Locally dependent on problems in present cassava growing and on market conditions	50% increases in expected profits/ha for overall system	0-5 years	Good

C: Utilization practices	Description of problems to be attacked	Region of Impact	Time lag until commercial adoption	Chance of adoption	
Fresh cassava storage	Postharvest deterioration	Urban Latin America Urban Asia	Avoidance of 10-15% postharvest losses Decreased fresh cassava margins Increased consumer demand	2-4 years	In areas where adopted, adoption will quickly reach 100%
Development of cassava drying operations	Low quality, seasonality of natural drying, drying time, cyanide decomposition	Carbohydrate-deficient tropical countries	Rural industrialization and employment Induction toward yield increasing technology	Now being adopted	Excellent
Cassava product development	Composite flour mixing, animal feed diets	Carbohydrate-deficient tropical countries	Rural industrialization and employment Increased utilization of local/nation resources	Animal feed now a reality 4-7 years for composite flours etc.	Composite flour moderate Animal feed excellent

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Appendix Table 19.5 Pipeline: New germplasm reaching release.

LLANOS	P%	CERRADOS	P%	HUMID TROPICS	P%
SHORT TERM (Next 5 years)					
Legumes		**Legumes**		**Legumes**	
Centrosema macrocarpum and *Centrosema* sp: accessions selected for their tolerance to *Rhizoctonia* and bacteriosis, as well as lower in soil fertility requirements	80	*Stylosanthes guianensis* "pauciflora" : selections better than "Bandeirante" (already released cultivar) in terms of seed production and palatability	80	*Stylosanthes guianensis*: selections environmentally adapted to survive and produce high-quality forage under anthracnose pressure	90
Arachis pintoii: legume compatible with aggressive grasses of *Brachiaria* spp	70	*Stylosanthes macrocephala*: better than "Pioneiro" (already released cultivar) in terms of persistence under grazing	80	*Desmodium ovalifolium*: selections with better palatability tolerance to stem gall nematode, and compatible with *Brachiaria* spp, as well as tolerant to shading	70
Stylosanthes macrocephala: alternative to *S.capitata* cv. "Capica", (already released in Colombia)	70	*Stylosanthes capitata*: selections tolerant to anthracnose and persistent under grazing	70	*Desmodium heterophyllum*: well adapted selections to low soil fertility; compatible with *Brachiaria* spp.	70
Grasses				**Grasses**	
Brachiaria brizantha cv "Marandú": EMBRAPA already released this grass in Brazil for its tolerance to spittle bug. May play an important role in this and other ecosystems	50			*Andropogon gayanus*: selections with better seedling vigor, able to compete better with weeds at establishment	50
Brachiaria dictyoneura: alternative to *B.decumbens* with better tolerance to spittle bug and better quality and higher seed production than *B.humidicola*	70				

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Appendix Table 19.5 (cont.)

LLANOS	P%	CERRADOS	P%	HUMID TROPICS	P%
MEDIUM TERM (5 to 10 years)					
Legumes		**Legumes**		**Legumes**	
S. guianensis (breeding lines) : selections tolerant to anthracnose high seed yielders and of improved palatability	50	Centrosema spp: selections of this genus with good seed yield potential and tolerance to drought stress	50	Arachis pintoii: compatible with Brachiaria spp.	50
				Stylosanthes spp: new selections tolerant to anthracnose	50
D.ovalifolium: selections tolerant to stem gall nematode and Synchitrium (false rust), as well as of higher palatability and quality	50	Zornia spp: selections of Z.latifolia and Z. glabra adapted to the upper Varsea environment	50	Centrosema spp: selections tolerant to Rhizoctonia, Cercospora and bacteriosis; also tolerant to shaded environments	50
Zornia glabra: selection of accessions tolerant to Sphaceloma and of higher persistance under a wide range of grazing management systems.	50	Pueraria spp: selections for well-drained, as well as upper Varsea environments, in the former case tolerant to drought stress; in the latter, to water logging	50	Zornia spp: selections of high quality and better palatability, tolerant to Sphaceloma	50
Pueraria spp: new selected species with lower fertilizer requirements than "Kudzu" and with better pasture attributes	50	Desmodium ovalifolium: selections for upper Varsea, with tolerance to "little leaf" mycoplasma	50	Pueraria spp: selections with better palatability and better persistence under grazing	50
S. capitata: new selections with better stability and persistance in association with aggressive grasses	30	Arachis pintoii: for upper Varsea environment	50	Shrubby legumes	
				Eritrina spp: forage and living fence selections	50
				Gliricidia spp: forage and living fence selections	50
				Native shrubby legumes: several selections for shade, living fence, and/or forage	50

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Appendix Table 19.5 (cont.)

LLANOS	P%	CERRADOS	P%	HUMID TROPICS	P%
Grasses		**Grasses**		**Grasses**	
P. maximum: selections with low fertilizer requirements and tolerant to spittle bug	50	Brachiaria spp: spittle bug tolerant new materials	50	Brachiaria spp: spittle bug tolerant, high-quality and high carrying capacity selections..	70
Brachiaria spp: selections of species and accessions tolerant to spittle bug	50	Panicum maximum: Spittle bug tolerant and low nutrient requirements	50	Panicum maximum: selections with lower nutrient requirements.	50
Andropogon gayanus: New short-statured selections more compatible with legume than CIAT 621 (already released)	70	Paspalum spp and Axonopus spp: selections adapted to the Chapada[2] and Varzea environments	50	Hyparrhenia rufa: selections with lower nutrient requirements.	50
				Axonopus spp: Shade-tolerant, highly productive selections	
				Paspalum spp: Shade-tolerant, highly productive selections	
LONG RUN (10 or more years)					
Legumes		**Legumes**			
Desmodium spp	20	Breeding lines and new accessions of		Difficult to visualize at at this point in time	
Centrosema spp	20				
Zornia spp	20	Centrosema spp	20		
Pueraria spp	20	Zornia spp	20		
		Stylosanthes spp	20		
		Shrubby legumes	20		
Grasses		**Grasses**			
Andropogon gayanus	20	Other new spittle bug tolerant grasses	20		

[1] Lowlands prone to seasonal poor drainage.

[2] High plateaus with grassy vegetation, very poor soils and prone to high water table.

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Appendix Table 19.6 Expected impact of pipeline pasture technology at the farm level.

Technology	Main Feature	Time Horizon Until Initial Impact	Area of Potential Impact	Probability of Success	Main Source of Uncertainty
SAVANNA ECOSYSTEMS					
Low-cost pasture establishment techniques	Reduce cost of land preparation using adapted plants and minimum till techniques; reduce fertilizer and seed costs by managing soil mineralization, rhizobial N fixation, VA mycorrhiza populations and slow-release fertilizers	short	300 million ha	high	Commercial viability of mycorrhiza management and of use of nonconventional fertilizers
Commercial fattening of steers on legume-grass associations	Increase production per head by about 50 kg/head/yr beyond level achieved on existing grass pasture	short	Farms close to markets	high	Availability of legume seed + credit for pasture establishment
Milk production on legume-grass associations	Expand dairy production into regions where previously not feasible	short	Smaller farms, close to markets	medium-high	Development of road and processing infrastructure, pasture seed + credit, genetic potential of prevailing cattle
Strategic use of improved pasture	Use small areas of improved pastures to: (a) supplement selected cows, (b) feed early weaned calves, (c) fatten cull cows; and (d) raise calving rates from 50% to 75%	short to medium	Extensive cow-calf operations distant from markets	medium-high	Low prices of land may make investment, even in low-cost improved pastures, not as attractive as closer to the markets; increased management requirements
Improvement of native savanna through introduction of legumes	Production of savanna limited mainly by forage quality; introduced legumes would increase quality and make burning unnecessary	medium	Extensive systems of both Llanos and Cerrado, where lands is cheap	medium	Increased management requirements; persistence and contribution of legumes still being studied
Development of integrated crop-livestock operations	Crops can improve cash flow of pasture establishment; accumulated fertility under pastures can be used for crop production and simultaneous reestablishment of pastures	medium	More intensive, arable areas of savannas close to markets	medium-high	Development of acid-tolerant varieties of main crops
Generalized adoption of legume-grass associations	Improve animal performance; increase stock numbers; expand utilization of frontier lands	long	300 million ha	medium	Income growth and growth in demand of beef and milk; policy decisions by governments
HUMID TROPICS					
Release of *S. guianensis* and *A. gayanus*	Both materials have been tested thoroughly and are expected to outperform presently available materials in this ecosystem	short	Land cleared in the Peruvian and Brazilian forest	medium-high	Seed availability
Reclamation of degraded grass pastures	Adapted legume and grass germplasm, limited amounts of phosphorous and appropriate management are expected to increase stocking rate from 0.5 to 2.0 an/ha and double weight gains per animal on a sustainable basis	medium	About 3 million ha of degraded pastures existent in the Amazon	medium-high	Credit, seed availability
Development of viable agrosilvopastoral systems	Integrated farming system with pastures and trees ranging from trees for shade and living fences in livestock operations to introducing pastures into tree plantations	medium	6 million ha (10% of humid tropics in Latin America)	medium	Markets for tree crops; increased management requirements

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Appendix Table 19.7

(1SEP84)

PIPELINE: MAIZE GERMPLASM

CHARACTERISTIC	APPROXIMATE AVAILABILITY NATIONAL PROGRAMS	POTENTIAL USE, AREA, YIELDS
(A principal pipeline product will be a continuing impfovement in the level and stability of yields from materials developed through the international maize network.)		
1. Downy Mildew	by 1987	10% yield increase in 80 percent of India and Philippine area, 30 percent Thai, Viet Nam, and South China area.
	by 1991	5% yield increase in humid lowland Africa (about 5,000,000 has.); in 20 percent area Mexico, in 30 percent area Guatemala, in 25 percent Peru and Venezuela, and in 20 percent Ecuador.
2. Streak Virus resistance	by 1989	5-10% yield increase in 10-15 percent area Sub-Sahara Africa.
3. Accommodate late drought	by 1991	15% yield increase on 25 percent of full season maize areas.

(Note: Now delivering materials with generalized capacity to accommodate drought.)

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Appendix Table 19.7 (cont.)

CHARACTERISTIC	APPROXIMATE AVAILABILITY NATIONAL PROGRAMS	POTENTIAL USE, AREA, YIELDS
4. Earliness	Now available but not fully distributed.	Offers drought escape and opportunity for intensification of cropping.
5. Army-worm resistance	by 1991	Up to 20% yield experience for areas suffering drought.
6. Ear worm resistance	by 1991	10% yield increase in Andean region.
7. Aluminum tolerance	by 1991	Some 10% yield increase on about 6m. million hectares in Brazil, Colombia, Mexico, Kenya, and others.
8. New Germplasm		
a. Soft floury	by 1991	For Andean, Paraguay, isolated areas Brazil; say 15% yield increase on 600,000 has.
b. Amazon humid	by 1995	For jungle areas Brazil and Paraguay, area unknown.
c. Inbred lines	by 1990	Wide interest.

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Appendix Table 19.8

(1SEP84)

PIPELINE: WHEAT GERMPLASM

CHARACTERISTIC	APPROXIMATE AVAILABILITY NATIONAL PROGRAMS	AREA OF POTENTIAL APPLICABILITY	APPROXIMATE YIELD ADVANTAGE	PRINCIPAL REGIONS/COUNTRIES FOR POTENTIAL USE
1. Accommodation to presence of free aluminum	1984 (Cultivars available now with improvements coming along steadily.)	10-15 M Has.	20-25% 150-200 kgs/ha	Brazil, Paraguay; Kenya, Zambia; Mexico; Others with acid soils and severe foliar disease
2. Earliness	1984 (Cultivars available now with improvements coming along steadily.)	10-20 M Has.	5-10% where late heat or drought reduces yield.	Sind of Pakistan NE India, Madra Pradesh India, Brazil, Paraguay China and Korea
			More intense cropping patterns in other areas with wheat yields roughly maintained.	Northern India Bangladesh, Pakistan, China.
3. Septoria (T) resistance	1985	5 M Has.	10-20% in years of infection. Say 3-5% average, 75-100 kgs/ha.	Mediterranean Basin, along coast. Southern Brazil and N. Argentina

Appendix Table 19.8 (cont.)

CHARACTERISTIC	APPROXIMATE AVAILABILITY NATIONAL PROGRAMS	AREA OF POTENTIAL APPLICABILITY	APPROXIMATE YIELD ADVANTAGE	POTENTIAL REGIONS/COUNTRIES FOR POTENTIAL USE
4. Heat Tolerance	1988	5 M Has.	15-20% in years of high heat, say 10% average. 100 kgs/has.	Brazil, N. Argentina, Sudan Sind of Pakistan NE India, Bangladesh,
			As well, this quality will open new areas to wheat production.	Burma, Central India.
5. Helminthosporium (S.)	1990	10 M Has.	10-20% in years of high infection.	Brazil, Bolivia, certain African countries.
			This quality will open up significant areas to potential wheat production.	
6. Scab Resistance	1990	5 M Has.	10-15%	China, Brazil, Paraguay, Uruguay, E. Africa.
7. Wide crosses for added resistance to disease and stress	1995	Widespread depending on character.	Significant increase in yield plus added yield stability.	Widespread.

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Appendix Table 19.8 (cont.)

CHARACTERISTIC	APPROXIMATE AVAILABILITY NATIONAL PROGRAMS	AREA OF POTENTIAL APPLICABILITY	APPROXIMATE YIELD ADVANTAGE	POTENTIAL REGIONS/COUNTRIES FOR POTENTIAL USE
8. Improved winter wheat germplasm	1990	20 M Has.	Up to 20%, say average of 10%. 100 kgs/ha.	China, Korea, Turkey, Iran, Afghanistan.
9. Better grain type for Triticale	1986	5 M Has.	50-10%, 75 kgs/ha.	Where drought, soils, and disease limit wheat production. New areas could be opened to small grains.
10. Stem rust resistance in Durums.	1987	3 M Has.	5-10% in years of infestation. 25-50 kgs. on average.	N. Africa, Ethiopia, Middle East.
11. Capacity to accommodate drought	1990 and following.	Widespread	10-15% with droughthy conditions, 25-50 kgs/ha average	Low rainfall areas.
12. BYVD	1988	30 M Has.	5-10% in years of occurrence. 75 kg/ha. average.	Most major wheat areas.

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