

TOWARD

the 21st Century

CIMMYT's Strategy

CIMMYT is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center is engaged in a worldwide research program for maize, wheat, and triticale, with emphasis on improving the productivity of agricultural resources in developing countries. It is one of 13 nonprofit international agricultural research and training centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). The CGIAR consists of a combination of 40 donor countries, international and regional organizations, and private foundations.

CIMMYT receives core support through the CGIAR from a number of sources, including the international aid agencies of Australia, Austria, Brazil, Canada, China, Denmark, the Federal Republic of Germany, Finland, France, India, Ireland, Italy, Japan, Mexico, the Netherlands, Norway, the Philippines, Spain, Switzerland, the United Kingdom, and the USA, and from the European Economic Commission, Ford Foundation, Inter-American Development Bank, OPEC Fund for International Development, UNDP, and World Bank. CIMMYT also receives non-CGIAR extra-core support from Belgium, the International Development Research Centre, the Rockefeller Foundation, and many of the core donors listed above.

Responsibility for this publication rests solely with CIMMYT.

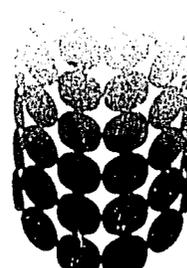
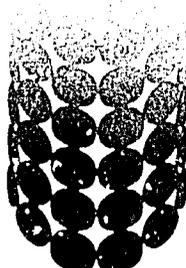
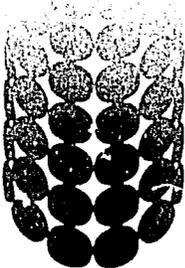
Correct Citation: *Toward the 21st Century: CIMMYT's Strategy 1989*. Mexico, D.F.: CIMMYT.

ISBN 968-6127-33-X

TOWARD

the 21st Century

CIMMYT's Strategy



a

Contents

A Note to the Reader

In developing the final version of the CIMMYT strategic plan, we have made a special effort to ensure easy access to the information it contains. It is written in a concise, economical style that we believe the reader will find appealing. Its design also contributes to clarity. We have abstracted our major thoughts, observations, and conclusions, placing them to the side of each page (just like this note). The essence of the plan can thus be gleaned by reading only the highlights. In addition, these highlights are placed in close proximity to relevant text, so that readers interested in more information on particular points can find it quickly and easily.

iv	Preface
1	Chapter 1 Introduction
3	Chapter 2 CIMMYT Today
4	CIMMYT's Mandate and Mission
5	The Values and Culture of CIMMYT
6	CIMMYT's Enterprises
7	The Maize Program
9	The Wheat Program
10	The Economics Program
11	Research Support Services
12	Headquarters, Regional, and Bilateral Programs
14	Sources of Funds
15	Conclusion
16	Chapter 3 CIMMYT's Future Environment
16	The Economic Environment
21	The Strength of National Agricultural Research Systems
24	Changes in Science
28	Alternative Sources of Supply
31	The Physical Environment
33	Chapter 4 Criteria for Decision Making
33	Expected Economic Returns
33	Impact on the Poor
34	Food Versus Feed
34	Stability of Yield
34	Human Nutrition
34	Alternative Sources of Supply
35	Strengthening National Programs
36	Operational Scale
36	Minimum Critical Mass
36	"Upstream" Research
36	Sustaining Natural Resources
37	Sub-Saharan Africa
37	Criteria Summarized
40	Chapter 5 Resource Allocations for the Future
40	The 1985 TAC Recommendation for Wheat
41	Allocations Between Maize and Wheat
46	Allocations to Economics and Support Services
47	Allocations Between Enterprises
49	Allocations Among Major Activities
53	Direct Support to National Systems, Revisited
55	Resource Allocations Summarized
56	Chapter 6 Future Operational Strategies
56	Germplasm Improvement
60	Crop Management Research

-
- 61 Economic Analysis of Research Priorities and Impacts
 - 62 Training
 - 63 Information
 - 64 Consulting Services

65 Chapter 7 Major Implications of the Plan

- 65 Structure and Organization
- 70 Implications for Staffing
- 71 Implications for CIMMYT's Culture
- 73 Implications for Physical Facilities
- 74 Implications for Funding
- 75 Implications for National Systems

76 Chapter 8 Monitoring and Evaluation

- 76 Monitoring
- 77 Evaluation

78 Bibliography

Tables

- 13 Table 2.1. Percentages of senior and associate staff time allocated to different activities, by place of assignment, 1988.
- 17 Table 3.1. Demand projections for maize by region (1985-2000).
- 17 Table 3.2. Demand projections for wheat by region (1985-2000).
- 18 Table 3.3. Area, yield, and production increases in maize and wheat (1970-85).
- 22 Table 3.4. A profile of developing country maize research programs.
- 23 Table 3.5. A profile of developing country wheat research programs.
- 29 Table 3.6. Trends among alternative suppliers of some CIMMYT products and services to 2000.
- 41 Table 5.1. CIMMYT senior and associate staff, by major unit, place of assignment, and funding, 1988.
- 42 Table 5.2. Quantitative indicators of criteria for research resource allocations between maize and wheat.
- 48 Table 5.3. Percentages of senior and associate staff time allocated to different activities, by place of assignment, 1988.
- 49 Table 5.4. Projected percentage allocations of senior and associate staff time among different activities, by place of assignment, to 2000.

Figures

- 3 Figure 2.1. CIMMYT headquarters, regional, and bilateral program offices.
- 4 Figure 2.2. International agricultural research centers belonging to the CGIAR.
- 8 Figure 2.3. The general organization of CIMMYT, 1989.
- 15 Figure 2.4. Sources of CIMMYT funds, a 12-year summary.

C

Preface

The diverse challenges and enormous opportunities of the coming decades require imaginative approaches to planning.

In 1987 and 1988, CIMMYT invested heavily in planning for the remainder of the century. We did so in the context of the Center's major goal—that of opening new options for the poor of developing countries—and of its major enterprises—research and direct support aimed at strengthening national agricultural research systems. Faced with limited resources but enormous opportunities, we saw the benefits of imaginative planning. My purpose here is to describe how we dealt with the challenge.

First, we were conscious of CIMMYT's long history of contribution. We were equally conscious of the accelerating pace of change around us. We had to resist inclinations to stay the course on the one hand or to be swept away from currently successful paradigms on the other.

As we reviewed our last decade we became aware of a surprising amount of change. While most of this occurred in the way we do things—adding to product quality and reducing costs—change also occurred in the mix of the things we do. Clearly, our *modus operandi* permitted change; we were not constrained to doing today what we were doing yesterday. We saw evident flexibility. Was it sufficient, however, for us to capitalize on the potential in the formidable changes occurring around us?

Many press CIMMYT to radically alter the course of its work. In particular, some argue that we move away from our conventional activities, shift our efforts toward basic science, where a tremendous amount of new knowledge is accumulating, and change our product mix from goods immediately useful to our clients to those a step or two away from immediate application. Who, though, would then ensure national systems a continuing flow of useful new products and, perhaps more important, guarantee ready access to a vast mix of improved germplasm should varieties in farmers' fields fall prey to disease or insects?

Strategic planning, with its emphasis on the needs of clients and on explicit projections of the future environment, provided a framework for addressing the challenges before us.

Confronted with diverse challenges, we clearly needed to extend our planning, needed to frame deliberate strategies toward the future, needed to do that in the context of CIMMYT's successful past and its productive staff, and needed somehow to anchor our planning in an explicit description of the major elements of our future. We looked for a planning format rich enough to accommodate these needed ingredients and flexible enough to accommodate the unexpected. We believe we found it in strategic planning.

Practitioners of strategic planning point to its emphasis on clients and on the future environment. Beyond these critical considerations the format has a place for culture, the shared values or beliefs that inhibit or encourage specific behavior patterns. As well, because of its emphasis on continuous review, especially of the evolving environment, it encourages adaptation to differences in the projected and the revealed paths toward the future.

CIMMYT strives to help poor farmers and consumers in developing countries. A little reflection, however, suggests that an international research center is ill equipped to deal directly with farmers and consumers. We can reach those ultimate clients through more immediate clients, the national agricultural research systems. For some time we have recognized these systems as our primary clients. It is to them that we deliver our products; it is from them that we acquire information essential to the formulation of our priorities. They, in turn, incorporate our offerings in developing technologies for farmers.

Developing country national systems include several elements. In the past the most important of these were the public sector research entities, referred to as national programs. In the future we see an expanding role in some countries for the private sector. We include public and private elements of national systems in ensuring that our planning is client driven.

Our operating environment is shaped by an array of forces. For purposes of planning, a few dimensions are far more important than the rest. We focused our attention on six dimensions identified as crucial to our own activities.

First, CIMMYT is a member of the CGIAR and its judgements play a major role in shaping our future environment. The System is committed to agricultural research and related activities that treat important topics, that are international in scope, and in which its centers are low cost producers. We expect no change in that stance. Since its inception, the System has required its centers to emphasize work aimed at the poor of developing countries, be they producers or consumers. Recently, it has elevated the issue of sustaining the productivity of agricultural resources. We see both these concerns as being of enduring importance. As well, the System is concerned with sub-Saharan Africa, marginal lands, and a shift of center emphasis from adaptive to strategic research.

A second dimension involves changes in maize and wheat markets. Measures of value orient the fixing of our priorities. We start that analysis by projecting the production and price of our crops. We then adjust direct economic values to reflect concern for the poor and for other System goals.

A third consideration is the strength of national systems, especially the publicly funded programs. As both users and potential alternative suppliers of our products and services, these systems comprise a critical dimension of our future environment. Fourth, science will open opportunities to CIMMYT and to national systems. We project likely developments, but recognize the overriding importance of the Center's sensitivity and flexibility in the rapidly changing environment of science. Fifth, as we look at CIMMYT's current offerings, we need to know the extent to which others might supply similar products at lower or equal costs. Public- and private-sector entities are potential sources. Where we judged such development to be likely we gave less weight to our own role.

Our clients are Third World national agricultural research systems...through them we seek to open options for the poor.

Six dimensions of our future environment are crucial to CIMMYT: We begin with CGIAR judgements about priorities and with projected changes in maize and wheat markets.

We also consider likely changes in the strength of national systems, in science, and in alternative sources of supply.

Sixth, we monitor changes in the physical environment.

Effective planning clarifies goals, priorities, resource allocations, and evaluation, and makes transparent the linkages among them. It requires analysis and judgement, and the direct participation of those having a stake in the outcome.

And finally, changes in the physical environment could profoundly affect agricultural productivity. While notoriously difficult to predict, environmental trends can be factored into research endeavors. Operationally, this means careful monitoring of environmental conditions in the developing world and responsiveness to fundamental changes in such conditions.

These six dimensions figured prominently in shaping our projected activities; they will continue as key reference points in determining our path toward the future. They provide the context within which we defined our goals, mission, and enterprises, set our priorities, and assigned resources; all this is found in Chapter 5. Beyond that, we examined major issues addressed by our operating strategies. Chapter 6 provides highlights; for a fuller discussion see the companion publication, *Toward the 21st Century: Strategic Issues and the Operational Strategies of CIMMYT*. Chapters 7 and 8 reflect on the implications of our plans for CIMMYT and on the issue of monitoring and evaluation.

As we planned, we brought more stakeholders into the plan. To varying degrees our entire professional staff has participated in all discussions; we believe that new highs were attained in interest and commitment. CIMMYT's Board of Trustees participated at critical points throughout the process. Representatives of national systems joined in at three separate stages before completion of our first draft. We are grateful for the energy and insight they brought to our task. As well, donors to the Center were given an opportunity to contribute. As we see it, then, the net was cast broadly and a rich harvest of perceptions, ideas, and counsel resulted.

We believe this plan is a long step towards transparency in the pathways connecting goals, priorities, resource allocations, and evaluation. We believe it represents a judicious blend of analysis and judgement, and that it will serve us well in opening options for the poor. We trust you will agree.

Donald L. Winkelmann
Director General

September, 1989

Throughout its rich history, CIMMYT has changed in response to changing circumstances. While it remains at heart a germplasm improvement institution, the CIMMYT of today is quite different from that of 20 years ago, just as CIMMYT in 2000 will be different from the CIMMYT of today. The challenge is one of charting a course, anticipating change wherever possible while providing for the unexpected. This challenge derives particular significance from the fundamental importance of maize and wheat in developing countries.

CIMMYT's contributions Since its inception, the Center has worked with national programs in developing countries to help increase maize and wheat production. In concert with researchers throughout the developing world, we have produced improved germplasm now found in the backgrounds of many commercial varieties grown by Third World farmers. Some 60 million hectares grow wheat varieties containing CIMMYT germplasm, and the annual value of added output is many, many times the cost of our activities. The spread of improved maize varieties in developing countries is less well documented, yet over 9 million hectares are now seeded to CIMMYT-related varieties.

Third World farmers and consumers have reaped tremendous benefits from our efforts and those of our national program colleagues. Contributions to science are also an important dimension of our work.

Germplasm improvement remains our primary means of opening new options for the poor. Even so, our work in crop management and on-farm research has done much to strengthen the research capabilities of national programs, as have our various training courses. Over 4,000 researchers from some 95 developing countries have received training at the Center. And our information and consultation services have helped reinforce the work of national program scientists.

Contributions to science comprise an additional, important dimension of our efforts. A partial list includes: identification of the yield determinants in wheat as well as the factors influencing broad adaptation; identification of factors affecting yield, adaptation, and improvement of tropical maize; pioneering research related to the accumulation of genetic modifiers in quality protein maize; and the development of innovative on-farm research methods.

Development of the CIMMYT plan While strategic planning is firmly anchored in the future, CIMMYT's current circumstances provided the context for assessing new needs. Certain aspects of our future environment and how they will influence our efforts were also a major element in planning, as were the criteria used to assign priorities and the various operational strategies employed by the Center. These four elements, all discussed in detail in later chapters, shaped our planning process.

Our challenge is to chart a course into the next century, anticipating change wherever possible while providing for the unexpected.

Early in the process, a number of issues were identified whose analysis were thought to be vital. These issues related to six general areas: 1) germplasm improvement, 2) crop management research, 3) basic and strategic research, 4) training, 5) information, and 6) national agricultural research

Throughout the planning process, we sought to increase the number of stakeholders in the plan, bringing into the effort those with an abiding interest in the outcome.

systems. Task forces corresponding to each area considered relevant issues and prepared reports organized around the most strategically important concerns emerging from their discussions.

We next met with representatives of developing country research systems and with donors to discuss and expand upon the issues analyzed in the task force reports. The views and concerns expressed at that meeting were incorporated into a preliminary draft of the plan. They also formed the basis of a questionnaire that was distributed widely among maize and wheat national programs in the Third world. Information garnered from responses to the questionnaire was used to develop a second draft of the plan.

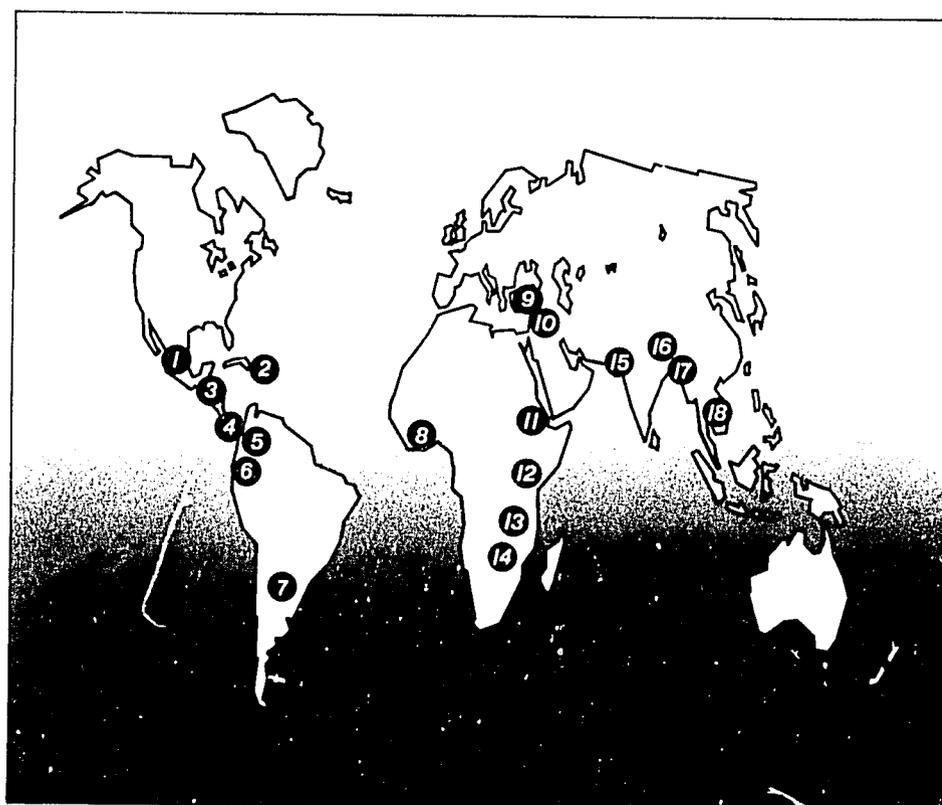
In January 1988 all CIMMYT staff and representatives of the Board of Trustees met at headquarters for an intensive internal review of the draft plan. In February we held regional meetings in Colombia, Kenya, and Thailand at which a total of 35 national systems were represented. Following these meetings, the plan was revised again and made available to the Board in mid-March. With the Board's input a penultimate draft of the plan was delivered in June to the CGIAR external program and management review teams for use in their August 1988 reviews of the Center. That draft served as the basis for their comments on CIMMYT's future. The plan and the reports of the review teams were first considered by TAC in November 1988. TAC's concerns are reflected in this, the final version of our strategic plan.

Notable in all this is the extent of the participation by Center staff, by the Board, by representatives of national systems, and by donors. What follows, then, rests on the contributions of the Center's most important stakeholders.

CIMMYT is an autonomous international, nonprofit, scientific research and training institution. From its headquarters in Mexico and from offices in a number of other locations around the Third World (see map, Figure 2.1), the Center operates a global program of maize, wheat, and triticale improvement, investigates economics issues related to these crops, and provides various forms of support to about 100 national agricultural research programs responsible for maize and wheat in developing countries.

CIMMYT is one of 13 research centers (see map, Figure 2.2) currently supported by the Consultative Group on International Agricultural Research (CGIAR, also referred to as the "CG" or "System"). The CG is an informal association of donors and research institutions that seeks to realize for the poor the high potential payoffs coming from well-focused international agricultural research. In setting guidelines for the work of the centers, the CG ensures that they confront challenges of international scope and enduring importance. Each center reconciles these guidelines with its own operational capabilities and experience and devises efficient strategies for addressing priority problems.

With guidance from the CGIAR, CIMMYT operates a global research and training program focused on maize, wheat, and triticale.



- 1 El Batán, México (headquarters)
- 2 Les Cayes, Haiti
- 3 Guatemala City, Guatemala
- 4 San José, Costa Rica
- 5 Cali, Colombia
- 6 Quito, Ecuador
- 7 Asunción, Paraguay
- 8 Kumasi, Ghana
- 9 Ankara, Turkey
- 10 Aleppo, Syria
- 11 Addis Ababa, Ethiopia
- 12 Nairobi, Kenya
- 13 Lilongwe, Malawi
- 14 Harare, Zimbabwe
- 15 Islamabad, Pakistan
- 16 Kathmandu, Nepal
- 17 Dhaka, Bangladesh
- 18 Bangkok, Thailand

Figure 2.1. CIMMYT headquarters, regional, and bilateral program offices.

Hence, there is a strong correlation between our goals and priorities and those of the CGIAR. We take as a given that our primary purpose is to open options to the poor in developing countries. We seek to do that by increasing the productivity of resources committed to maize and wheat, whether in research or in production. While our ultimate client is the farmer, our work is focused on and channeled through national research systems, especially the publicly funded national programs we view as our immediate clients.

CIMMYT's Mandate and Mission

While CIMMYT's mandate remains unchanged, the Center's mission has been refined over the years in response to new realities.

■ On April 12, 1966, CIMMYT was established as a nonprofit organization responsible to an internationally elected board of trustees. The Ford and the Rockefeller Foundations, together with Mexico, were the Center's initial principal supporters. At its inception, the Center was given a broad, multifaceted mandate:

To promote and carry out, nationally and internationally, programs to improve in all its aspects maize and wheat production...through research, the distribution of germplasm, training, scientific and technical meetings, and information.

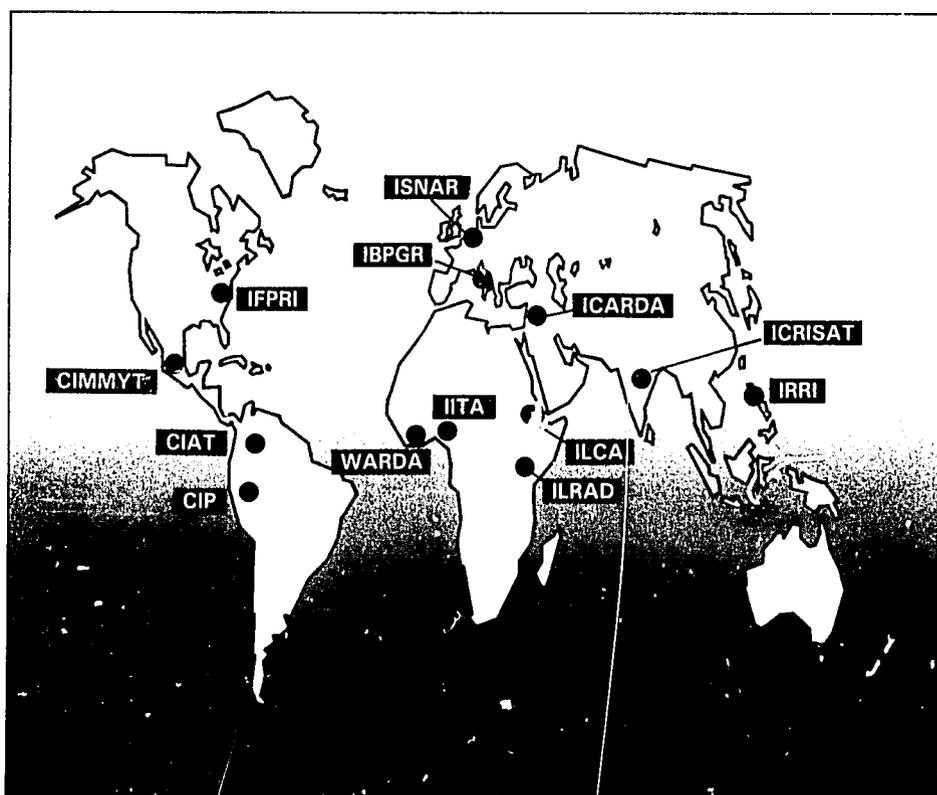


Figure 2.2. International agricultural research centers belonging to the CGIAR.

The aims suggested by this broad mandate were more succinctly expressed in a forceful mission statement:

To increase the quantity and quality of maize and wheat produced in the developing countries of the world.

While the Center's mandate has remained the same, of late it has come to be interpreted differently. During the 1980s, the Center began to view its mission as one of improving the productivity of agricultural resources, rather than increasing the production of maize and wheat, *per se*. Strategic planning has produced additional refinements, as reflected in our current mission:

To help the poor of developing countries by increasing the productivity of resources committed to maize and wheat, whether in research or on the farm; improved germplasm, new knowledge and information, research procedures, training, and consulting services are our principal means to this end.

Notice that this reformulation of our mission features the Center's commitment to helping the poor of developing countries. It clearly reflects our concern for the productivity of resources used in research, both by CIMMYT and in national programs. It also reflects our abiding interest in enhancing productivity at the farm level, with our contributions in this arena being made through national programs. Less obvious, perhaps, but no less important is our expanded commitment to the conservation of genetic resources, as well as other resources needed to ensure future productivity.

The Values and Culture of CIMMYT

■ Many of the Center's current values and much of its culture can be traced to the challenge that led to the institution's creation. At that time, the world faced severe food shortages and there was little that stood between many of the world's poor and starvation. A small group of dedicated individuals saw promise in the development of improved varieties through the concentrated application of basic principles, some new ideas, and a lot of hard work. These scientists centered their work on germplasm improvement in an integrated, multidisciplinary approach, and pursued success at the farm level. Training national program staff in the ways of applied science was seen as an essential part of the job, and considerable energy went into developing an international network of agricultural scientists working toward a common goal. The tremendous combined efforts of the people who were caught up in those heady times paid off handsomely, launching a "Green Revolution" that brought new hope to a hungry world.

The forceful rallying cries of an earlier day have been supplanted by more subtle calls to action.

The immediacy of the early challenge to "fill hungry bellies" left a distinct mark on the way we go about our work.

The success of that effort left a distinct mark on the way CIMMYT staff go about their work. The immediacy of the earlier challenge gave rise to a strong belief in the importance of a pragmatic approach to agricultural research, and of getting out into the field with national program colleagues to wrestle with the problems at hand. So, too, did we come to emphasize the effectiveness of national programs, an evenhandedness in dealing with clients, and a nonpolitical stance. These elements remain fundamental to our long-term success. As well, continuous funding and our relative stability in staffing give us freedom to take the long view, an advantage shared by few international and national organizations.

The ethos of CIMMYT today is much the same as at its inception, and serves to distinguish the Center from similar organizations.

Thus, some critical things about CIMMYT have *not* changed over the years. The ethos of the Center today is very much the same as at its inception: an emphasis on field work, on the importance of direct researcher involvement, on a pragmatism based on the needs of farmers, and on the benefits and obligations of an open association with a worldwide network of practitioners sharing the same principles. These values and related behavior serve to distinguish the Center from similar organizations, and contribute to its continued success. Whether the current organizational culture will be appropriate in all its dimensions for meeting the challenges we will face in 2000, however, is an open question. Indeed, some shared values and beliefs are likely to change as our circumstances change over the next decade (see Chapter 7).

CIMMYT's Enterprises

Research and direct support to national programs are our primary enterprises.

■ CIMMYT's primary enterprises are research and direct support to national programs. Both aim at strengthening national research systems so that they can more effectively serve farmers. The Center's research occurs in three major areas: germplasm improvement, crop management, and economics. Germplasm improvement activities, which clearly constitute our major emphasis, are supported by disciplinary research in crop protection, plant nutrition and crop management (agronomy), and by a number of specialized operations in germplasm conservation, wide crosses, experiment stations, information, and laboratories.

Our contributions to national programs rest on our capacity to conduct relevant, high quality research. Our research products are complemented by direct support to national programs in the form of training, information, and consultation. Through our activities, we provide clients with five primary products and services:

- Improved maize and wheat germplasm for major production environments in the Third World
- Efficient methods for plant breeding, crop management research, and agricultural decision making, especially in research

- Training of various types
- Scientific information stemming from the Center's own research and from the work of others
- Consulting services (technical consultation and assistance)

These products and services are provided by staff working in the Center's three main programs—Maize, Wheat, and Economics—assisted by several research support units and general administrative services (see Figure 2.3).

The Maize Program

■ Research on maize germplasm involves the development and improvement of populations. *General purpose populations* contain broad-based materials, each representing one of the various maize types grown in developing countries. The Program also develops *special purpose populations*, which comprise agronomically acceptable materials that can serve as sources of tolerance to specific biotic or abiotic stresses. *International progeny trials* focus on advanced materials from which experimental varieties are developed. Products from these populations are distributed to national programs in developing countries, mainly in the form of variety trials. Germplasm improvement and distribution efforts are supported by specialists in pathology, entomology, physiology, crop management research, wide crosses, the conservation of genetic resources, hybrid development, and international nurseries.

Maize research and training in CIMMYT are conducted by a multidisciplinary team of 43 senior and associate staff, plus a number of post doctorals. Twenty-four are located at headquarters and 19 are deployed outside Mexico among six regional maize programs, one bilateral project (serving Ghana), and one cooperative research venture (with the International Institute of Tropical Agriculture, IITA, concentrating on the improvement of tropical lowland germplasm for West and Central Africa under terms of an agreement reached in 1988). Maize Program headquarters-based senior and associate staff are augmented by some 37 national support staff.

Most headquarters-based staff are involved in germplasm improvement activities, while those in the regions now focus relatively more on crop management research and on direct support to national programs. Some regional staff also engage directly in germplasm improvement research, in those instances where the research is not readily practicable at headquarters (such as for downy mildew or corn stunt resistance). Regional maize staff are found in the Andean zone, Central America and the Caribbean, Asia, the Middle East/North Africa, Eastern Africa, and Southern Africa.

Our research...in germplasm improvement, crop management, and economics...provides valuable products as well as the basis for more direct forms of support to national programs... training, information, and consultation.

Germplasm improvement is the primary goal of both the Maize and Wheat Programs, though crop management research (CMR) has become more important in recent years, especially in Wheat.

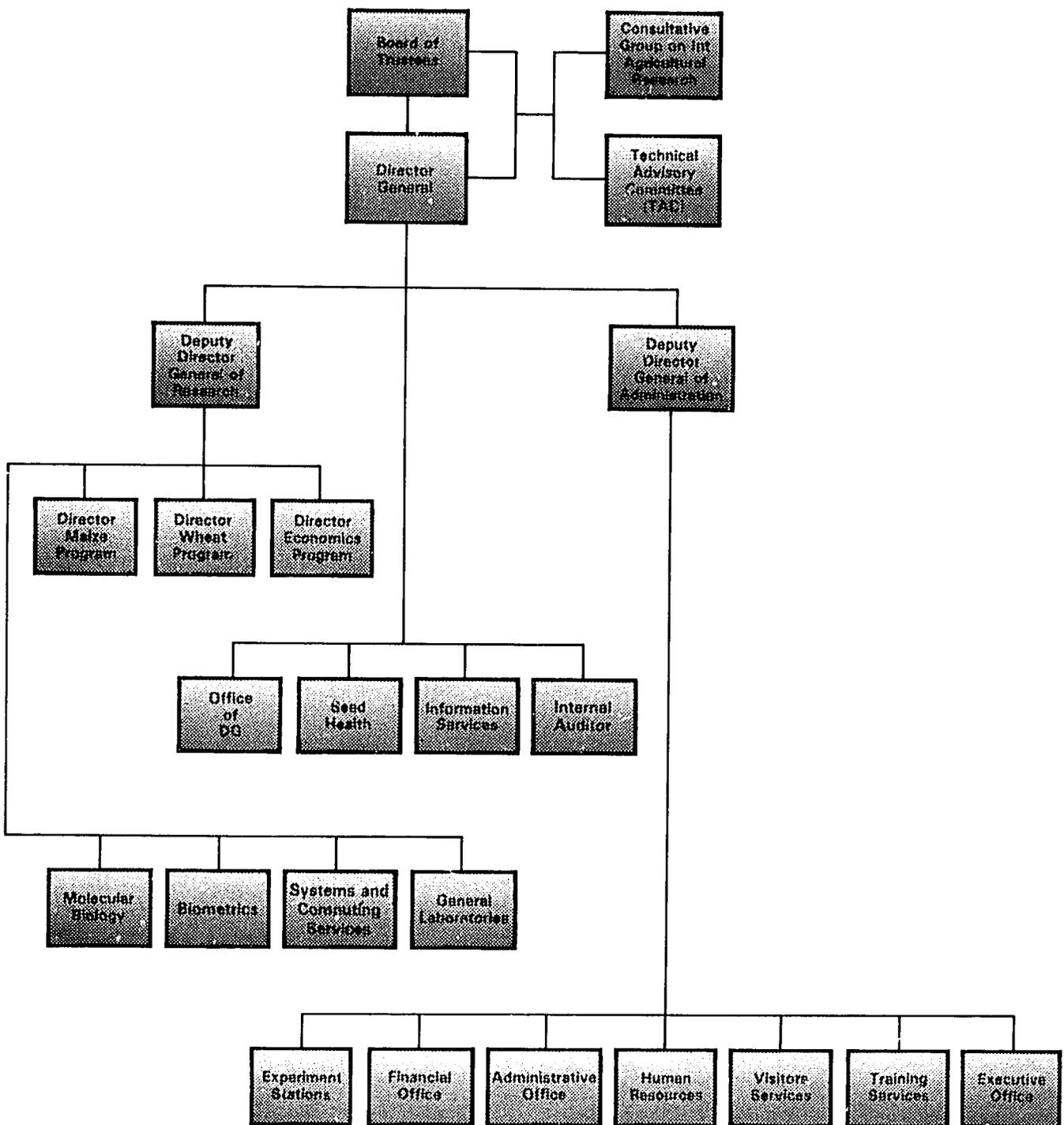


Figure 2.3. The general organization of CIMMYT, 1989.

Note: This diagram shows reporting relationships only. The reader should infer nothing about the relative importance or size of various offices/activities.

On January 1, 1989 the Maize Program implemented some notable changes in its organization, adding decision points to its structure so as to enhance management efficiency. Changes were made in three areas. At the Program management level, the associate director now has primary responsibility for the management of Maize Program activities outside Mexico, while the director will manage all headquarters-based activities. The Program was divided into nine subprograms, which together constitute a second organizational tier. Four of these subprograms focus on germplasm improvement: lowland tropical, subtropical, highland, and hybrids. The remaining subprograms are crop management and physiology, germplasm distribution, crop protection, genetic resources, and training. Each subprogram has a coordinator whose responsibilities include establishing research priorities in concert with staff in the subprogram, facilitating research planning, and contributing to the evaluation of research endeavors. Finally, team leaders were designated for each regional and bilateral location. Their responsibilities involve on-site management of Maize Program resources, in conformance with priorities established for the subprograms.

The organizational structure of CIMMYT capitalizes on the advantages afforded by a strong commodity orientation, yet captures the benefits of disciplinary efforts.

The Wheat Program

■ Germplasm research in the Wheat Program is organized around four crops. Spring bread wheat, which covers by far the largest area of the four in the developing world, receives the bulk of the Program's resources. Durum wheat, which is grown primarily under limited moisture conditions in developing countries, is the second largest crop program. Triticale, a cross between wheat and rye, shows promise for semiarid environments and for highland and acid soil areas; it is considered something of a speculative investment and therefore commands a lesser share of the Program's resources. Winter and facultative wheats, which are found on extensive areas in certain developing countries (especially Turkey and China), together comprise a new addition to the Wheat Program's research agenda and correspondingly consume at this time a relatively small portion of the Program's resources. Germplasm research is supported by specialists in crop protection (pathology and virology), crop management research and physiology, milling and baking quality, genetic resources, special germplasm development, wide crosses, seed health, and international nurseries.

Wheat research and training are conducted by 42 senior and associate staff, 27 at headquarters and 15 located outside Mexico in five regional programs, one bilateral project (serving Bangladesh), and two collaborative research programs (one with Turkey, focusing on winter wheats, the other with the International Center for Agricultural Research for the Dry Areas, ICARDA, focusing on spring bread wheat and durums for dry environments). The Wheat Program is involved in two formal research partnerships, one with India that focuses on Karnal bunt and one with China that is centered on fusarium head scab and the helminthosporium diseases of wheat. The Program also collabo-

Recently, the Maize and Wheat Programs implemented notable changes in their organizational structures, adding decision points to improve management efficiency.

The Maize, Wheat, and Economics Programs all have strong collaborative ties to an array of institutions pursuing related goals.

rates with ICARDA in research on barley by providing material support for their staff stationed at CIMMYT headquarters. Wheat Program headquarters-based senior and associate staff are augmented by some 97 national support staff.

As in the Maize Program, most Wheat staff located at headquarters engage in germplasm improvement activities, though crop management research at base figures more prominently than in Maize. Regional wheat staff spend much of their time in direct support of national programs and contribute significantly to the development of improved germplasm by providing information on the performance of CIMMYT nursery materials in their regions. Staff working in Turkey and Syria (ICARDA) have some regional responsibilities, but the bulk of their time is devoted to research. Regional staff are located in the Andean zone, the Southern Cone of South America, Eastern and Southern Africa, South Asia, and Southeast Asia.

The Wheat Program made significant changes in its organizational structure in early 1989. The purpose of the reorganization was to decentralize management by adding decision points to the structure and to foster additional disciplinary research. Four subprograms were created along disciplinary lines: germplasm improvement, genetic resources, crop protection, and crop management and physiology. Each has a leader responsible for research management at headquarters and, to a lesser extent, in regional and bilateral programs. The subprograms are composed of sections. For example, the genetic resources subprogram contains the germplasm bank, wide crosses/biotechnology, and germplasm enhancement sections. Each section has a head who works with section staff, subprogram leaders, and the Program directors to establish research priorities, plan activities, and evaluate the effectiveness of research.

The Economics Program

■ Economics became CIMMYT's third major research program in the early 1970s. There are now 15 senior and associate staff engaged in various aspects of economics research. Five are located at headquarters, and 10 are involved in cooperative research and training activities in 4 regional programs and 3 bilateral projects (serving Mexico, Pakistan, and Haiti). Headquarters-based senior and associate staff are augmented by six national support staff.

Staff at headquarters are involved in developing research methods for technology design and evaluation, assessing prospective technologies emanating from CIMMYT, evaluating research impacts and alternatives, and broad-based studies of the maize and wheat economies and of policy influences. The aim of regional and bilateral staff is to strengthen the capacity of national research programs to carry out agricultural research. Part of this objective is achieved through the development and teaching of research methods, primarily for conducting adaptive on-farm research. Regional economics staff are found in Central America and the Caribbean, Eastern Africa, Southern Africa, and Southeast Asia.

Economics research in CIMMYT is focused on issues relating to maize and wheat, and considerable attention has been given to developing on-farm research methodologies.

The Economics Program currently engages in collaborative research and training with the International Rice Research Institute (IRRI), the International Food Policy Research Institute (IFPRI), and the International Center of Tropical Agriculture (CIAT). It also maintains regular contact with several other sister institutes, exchanging data and analyses, collaborating in publication of research findings and methodology manuals, and occasionally conducting joint regional training programs.

Research Support Services

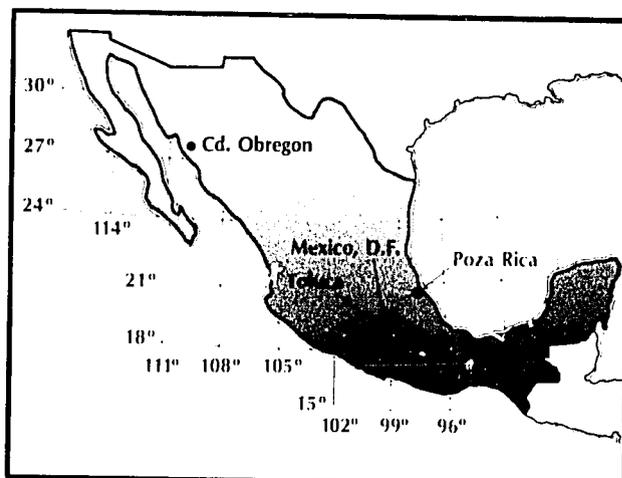
■ The Center's research support units include laboratories, experiment stations, information services, data processing services. The Deputy Director General of Research has long had oversight responsibilities for most of these support activities.

Laboratories Some CIMMYT labs serve only one or the other of the programs and are managed by the relevant program director. Three general laboratories, however, provide support to more than one program. The first of these is the cereal quality lab, which focuses its attention on assessing nutritional quality with special emphasis on quality protein maize. The second is the soil and plant tissue lab, which evaluates tissue samples for program scientists and tests for micro- and macro-elements in soil samples. These two labs also evaluate materials for tolerance to high levels of aluminum in acid soils. The third general lab is concerned with seed health, its primary function being to ensure that incoming and outgoing germplasm is disease free and appropriately treated for seed-borne pathogens. These three laboratories have a total staff of 22 (1 senior staff, 1 associate, and 20 support staff).

Our laboratory facilities are expanding with the construction of a molecular biology lab, due to become operational in late 1989.

The Center is now constructing a molecular biology laboratory that will house its new biotechnology unit. Once operational (in late 1989), the primary function of the unit will be to identify and adapt molecular techniques that promise to reduce the costs or increase the speed of our germplasm improvement operations. Training will also be offered. This unit will be staffed initially with one and later with two senior professionals, as well as several support staff. In coming years the work will be augmented by post-doctoral positions and visiting scientists.

Experiment stations In Mexico, the primary responsibility of experiment station staff is to oversee field operations on some 500 hectares of land at various research stations and other experimental sites (see map). CIMMYT works on five stations in Mexico, four of which (El Batán, Poza Rica, Tlaltizapan, and Toluca) are managed directly by Center staff and the fifth (near Ciudad Obregon) by Mexico's National Institute for Agricultural, Livestock,



and Forestry Research (INIFAP). As the Center's research agenda has broadened to address the problems of more marginal production environments, Mexico has made more than a dozen other research sites available to us. Logistical support and access to hundreds of additional sites are provided by collaborating national research programs throughout the developing world. Four senior staff manage experiment station operations and coordinate the efforts of 49 support staff, some 340 full-time field staff, and a host of part-time staff.

With guidance from central administration, staff working in labs, experiment stations, information, computing services, and biometrics seek to support the CIMMYT research function.

Information services This group consists of three interrelated units: publications, a scientific information unit (SIU) that includes our specialized library, and an audiovisuals/training materials development unit. Information services are oriented both toward supporting the Center's own research and toward providing direct support to national programs in the Third World. Staff work with Center scientists to more effectively communicate their research findings to various audiences, to remain current in their respective fields by providing efficient access to relevant research done elsewhere, and to improve the effectiveness of their training activities. There are 33 staff in information services (3 senior staff, 5 associates, and 25 support staff).

Systems and computing services This unit provides support to all the major operational areas, including research, administration, information services, accounting, and experiment stations. It consults with staff on various types of computer-based and statistical analyses, develops new special purpose software, installs and attends to the operational aspects of computer hardware, and assists computer users. Data processing services have expanded rapidly as the Center has sought to improve and streamline its management of research data and various administrative information services. There are now 29 staff in the unit (1 senior staff, 1 associate, and 27 support staff).

Biometrics This unit was created in early 1988 to formalize and augment the mathematical and statistical support to the research programs. There is one senior staff and one associate in the unit.

Central administration The Director General's office, administration, finances, and intergovernmental relations together comprise central administration. Primary functions include: providing overall direction and coordination in policy formulation; developing and maintaining relationships with Mexico, donors, other international centers, and key clients; and directing the house-keeping activities of the Center. Eight senior staff work in this area, assisted by 222 support staff.

Headquarters, Regional, and Bilateral Programs

■ Table 2.1 shows the allocation of staff time by activity and location. About half of all non-administrative activities are in research, and within that group germplasm improvement is most important. The second largest item is human resource development. Much of this work takes place at headquarters in formal

courses involving our training officers and other scientific staff, but much also occurs in regional and bilateral programs through in-country training and informal exchanges.

Activities in Mexico Much of the research and training done by the Center takes place in Mexico. The experimental sites we use, along with a number of other testing locations that vary from year to year, provide researchers with environmental conditions representative of a number of key maize and wheat producing areas in the developing world.

The Center offers in-service courses in maize improvement, maize production research, quality protein evaluation, wheat improvement, wheat pathology, wheat agronomy, cereal technology, and experiment station management. Each year some 150 in-service trainees, as well as visiting scientists, pre- and postdoctoral fellows, and senior research fellows make use of facilities and experiment sites in Mexico.

Administrative activities aside, about half of the Center's resources are currently devoted to research; the remainder goes to training, information, and consulting efforts in direct support of national programs.

Regional programs CIMMYT's regions are defined as groups of countries, usually contiguous, that have some production environments and problems in common. More importantly for national program development, these regions usually share common languages and customs, and have similar research structures. Staff are posted to regions that have a significant output of wheat or maize and where national programs agree to exchange germplasm and scientific information in order to better utilize scarce research resources.

Table 2.1. Percentages of senior and associate staff time allocated to different activities, by place of assignment, 1988.

Activity	Headquarters	Regional and bilateral programs	Total
Germplasm improvement	21.9	7.3	29.2
Crop management research	3.6	2.4	7.0
Social science research ^a	1.8	1.0	2.8
Total research	27.3	10.7	38.0
Training	9.7	10.2	19.9
Information ^b	4.5	2.8	7.3
Consulting	2.8	8.0	10.8
Total direct support	17.0	21.0	38.0
Administration	13.9	4.0	17.9
Other	5.3	0.8	6.1
Total administration/other	19.2	4.8	24.0

a Done by the Economics Program; much of the work in economics is included in crop management research.

b Contributions of Information Services staff were allocated 50% to direct support of national systems, 25% to administration, and 25% to headquarters research.

Note: Post-docs are not included in this table.

Regional staff engage in a range of activities that add to CIMMYT's research capacity and strengthen national programs.

Regional staff work with national program colleagues, assisting them in certain aspects of the design and implementation of research programs. At the same time, they inform headquarters about the performance of germplasm and identify opportunities for disseminating our products and services at the regional or national level. Consulting, research procedures, human resource development, and information are important services provided by regional program staff. They also support headquarters research by carrying out additional activities that cannot be done at headquarters, such as germplasm improvement for certain environments not represented in Mexico, crop management work for specific macro-environments, testing on-farm research procedures, or screening nurseries in certain "hot spot" areas.

While bilateral work has a national focus, its results also benefit our research and training programs.

Bilateral programs Activities in bilateral programs emphasize direct collaboration with national programs that have need of our research expertise or training skills. While the association has a national focus, such as strengthening the national program in Ghana, a prerequisite for our involvement is that the experience gained from working directly in a country will benefit the Center's overall research and training programs. The experience gained from working on the rice/wheat rotation in Bangladesh, generating maize technology in Ghana, or developing research procedures in Haiti must be general enough to benefit CIMMYT and ultimately other national programs.

Sources of Funds

Overall growth has slowed in recent years, and our reliance on extra-core funds has increased somewhat.

■ During the past 10 years, the Center's total funding has grown by about 173%, from some US\$ 12 million in 1977 to \$32.8 million in 1988. Meanwhile, the number of senior staff and associate scientists increased from 104 in 1977 to 124 in 1988. Growth has slowed during the past five years, however, reflecting the general funding trends in the CGIAR and the earlier influence of an undervalued peso in Mexico.

Trends in the composition of total funding lends additional perspective to the Center's financial situation. As in other CGIAR centers, funds are of three basic types: core unrestricted, core restricted, and extra-core grants. Core unrestricted funds traditionally constitute the bulk of the Center's financial resources, though their relative importance has varied over time. These three sources react to somewhat different forces. Core restricted funding tends to be the most stable. In CIMMYT's case the fastest growing source of funds has been extra core, rising from 11% to 18% of total funding from 1977 to 1988. Much of our extra-core support goes to bilateral projects, such as those in Ghana, Bangladesh, and Pakistan. Figure 2.4 provides a 12 year summary of our funding base.

Conclusion

■ CIMMYT is a dynamic and resilient organization whose primary asset is its skilled, specialized staff working in Mexico and throughout the developing world. Our organizational culture, a product of more than 40 years of experience in Mexico and the Third World, reinforces current patterns of work and meshes well with our current products and services. Like all organizational cultures, ours, too, inhibits some forms of change; even so, it has permitted rapid adaptation to changing circumstances. Our current offerings, firmly based on the expressed needs of the Center's immediate clients, are appropriate for the times; as times changed, so too has the mix of our offerings. Our organizational structure, with its current emphasis on regional activities, is also a product of the expressed needs of national program clients. Until very recently, little organizational change has occurred, despite significant growth in the size of the Center. Strategic planning recognizes the influence of history on our current circumstances and allows us to shape future practices in light of the anticipated needs of clients.

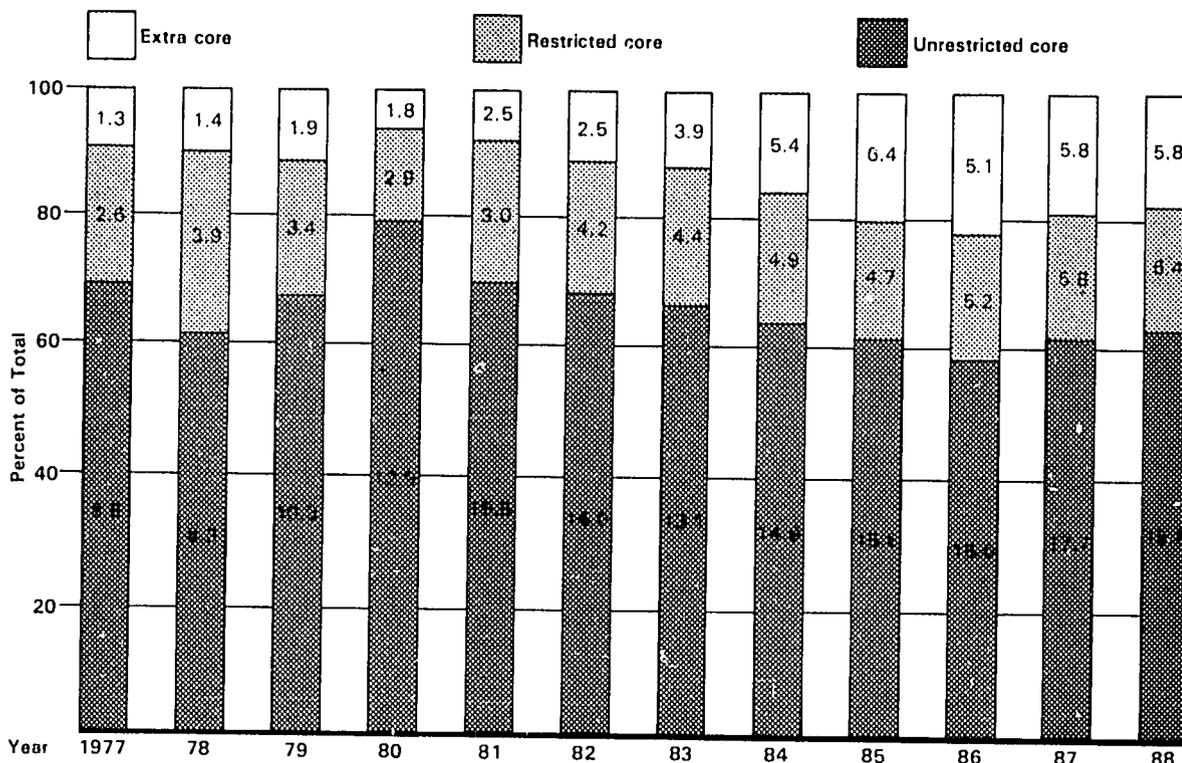


Figure 2.4. Sources of CIMMYT funds, a 12-year summary (figures in bars represent U.S. \$ millions).

Note: The increase in core funds for 1988 was due to high local inflation and a constant exchange rate, which led to a significant claim on the CGIAR stabilization fund.

There are six environmental elements of special importance to our planning.

Anticipating economic change is notoriously difficult, but is fundamental to sound strategic planning.

In the long run, global supplies of maize and wheat are predicted to stay ahead of demand.

As we set about strategic planning, several elements of our future environment were identified as being of special importance. First among them is the institutional environment facing the Center, i.e., the policies and guidelines established by the CGIAR. Because of its influence on our decision criteria, we defer discussion of the CGIAR environment to Chapter 4.

Other critical environmental elements include markets for maize and wheat, progress by national programs toward enhancing their research and training capacities, changes in science, changes in the physical environment, and the availability of other alternative suppliers of CIMMYT's products and services.

The Economic Environment

■ In assessing the economic environment to 2000, we examined the long-term global supply and demand situation for maize and wheat, as well as supply and demand in developing countries. We were especially concerned about emerging gaps between supply and demand, and about changes in the relative prices of the two commodities and in the relative prices of important inputs used in their production.

Supply and demand projections are, of course, subject to a considerable margin of error. World economic growth has slowed notably at the same time that international capital flows, exchange rates, and commodity prices have become more volatile. In the case of developing countries, heavy foreign debt creates added uncertainty about the economic environment as well. While substantial macro-level policy reforms have been undertaken by many developing countries in the 1980s, it is still too early to predict their consequences.

Recently the International Wheat Council (IWC 1987) and the Food and Agricultural Organization of the United Nations (FAO 1987) made detailed supply and demand projections to 2000 for wheat and coarse grains. These studies provided the basis for our own projections.

Global projections for maize and wheat Looking first at demand, annual growth rates of 2.6% and 2.2% are forecasted for maize and wheat, respectively. These projections are portrayed in Tables 3.1 and 3.2.

Changes in maize and wheat production over the period 1970 to 1985 are given in Table 3.3. IWC made notably pessimistic projections concerning the production of wheat and coarse grains. The FAO projections for production are more optimistic and, to us, more realistic, especially for coarse grains (an annual increase of 3.3% is forecast). For both maize and wheat, the FAO's projected increases parallel the projected increases in demand.

Table 3.1. Demand projections for maize by region (1985-2000).

	1985		2000		Annual growth rate	Annual growth rate	Annual growth rate
	Food maize (million tons)	Feed maize (million tons)	Food maize (million tons)	Feed maize (million tons)	Food maize (%)	Feed maize (%)	Total maize (%)
Developing countries:							
Sub-Saharan Africa	14.9	1.5	23.6	2.5	3.1	3.5	3.1
Middle East:							
N. Africa	7.6	4.3	10.6	7.9	2.2	4.1	3.0
Asia	43.8	53.1	49.7	118.9	0.8	5.5	3.8
Latin America	9.1	29.1	12.2	49.8	2.0	3.6	3.3
Total LDCs	75.4	88.0	96.1	179.1	1.6	4.9	3.5
Developed Countries	14.0	231.0	14.1	307.8	0.0	1.9	1.8
Total World	89.4	319.0	110.2	486.9	1.4	2.9	2.6

Source: Longmire (1987)

Table 3.2. Demand projections for wheat by region (1985-2000).

	1985		2000		Annual growth rate	Annual growth rate	Annual growth rate
	Food wheat (million tons)	Feed wheat (million tons)	Food wheat (million tons)	Feed wheat (million tons)	Food wheat (%)	Feed wheat (%)	Total wheat (%)
Developing countries:							
Sub-Saharan Africa	6.6	0.1	14.0	0.1	5.1	0.0	5.1
Middle East:							
North Africa	58.1	3.4	88.4	6.2	2.8	4.1	2.9
Asia	156.3	5.5	237.4	11.9	2.8	5.3	2.9
Latin America	25.4	2.4	38.0	4.4	2.7	4.1	2.9
Total LDCs	246.4	11.4	377.8	22.6	2.9	4.7	3.0
Developed Countries	154.0	89.0	169.3	123.5	0.6	2.2	1.3
Total World	400.4	100.4	547.1	146.1	2.1	2.5	2.2

Source: Longmire (1987)

Long-run global projections show maize and wheat supplies growing apace with demand, and most predict a continued decline in the real prices of cereals. Even so, prices are expected to remain volatile, with the potential for sharp, short-term increases. Still, in the long run, global supply should stay ahead of demand. The story in developing countries, however, is less optimistic.

The story in developing countries, however, is complicated and perhaps less optimistic than global projections would imply.

Developing country demand for maize and wheat Annual growth in demand is projected to be 3.5% for maize and 3.0% for wheat from 1985 to 2000 (see Tables 3.1 and 3.2). Developing countries will be by far the most important source of growth in global demand for the two commodities. These projections are based on an annual Third World population growth rate of 2.0%, an average annual per capita income growth rate of 2.6%, and a continuing trend toward urbanization (projected to increase from 31% in 1985 to 40% of developing country population by 2000). Note that significant regional differences in population and income growth were considered in the analysis, but that price considerations were not included in the projections.

Growth in demand for maize will exceed that for wheat.

On a regional basis, growth in demand for wheat is expected to be highest in sub-Saharan Africa where, even without rising incomes, per capita wheat consumption is increasing rapidly. For nearly all regions growth in demand for maize will be driven by its increasing use for animal feed (feed use in the

Table 3.3. Area, yield, and production increases in maize and wheat (1970-85).

	Annual growth rate					
	Area		Yield		Production	
	Maize	Wheat	Maize	Wheat	Maize	Wheat
Sub-Saharan Africa	0.8	-1.2	1.1	2.3	1.9	1.1
Middle East/ North Africa	0.5	0.3	2.2	2.6	2.7	2.9
Asia	1.1	1.6	3.5	4.8	4.6	6.4
Asia, excluding China	1.3	2.1	2.1	3.0	3.5	5.2
Latin America	0.3	1.3	2.2	2.5	2.5	3.9
All Developing Countries	1.0	1.2	3.0	4.1	4.0	5.3
All Developing Countries, excluding China	0.7	1.2	2.0	2.8	2.7	4.1
Industrialized Countries	0.9	0.1	2.6	1.9	3.5	2.0
World	0.8	0.5	2.7	2.6	3.5	3.0

Source: FAO (1987)

developing world is projected to grow at 4.9% per year, compared to 1.6% for food use). By 2000, the proportion of maize used as animal feed will be about 66%, up from 54% in 1985. Only in sub-Saharan Africa will the growth in demand for maize be fueled by its increased use for food.

Demand for maize as feed will exceed that for food.

Developing country production of maize and wheat The outlook for maize production is difficult to determine. The FAO projects increases of 3.6% per year, compared to increases of 4.0% for the period 1970-85 (the growth rate during that period was 2.7% per year if China is excluded). As the developing world's largest producer, much depends on the emphasis that China gives to production. We believe that good opportunities exist for raising the rate at which maize production increases will occur in the developing world. Newly improved germplasm is becoming available and national programs are moving to incorporate it into their own work.

The FAO projects an annual increase in wheat production of 3.0% to 2000, a considerable slowdown compared to the period 1970-85 (see Table 3.3). Even so, given the large increases of the recent past we are somewhat less optimistic about the immediate future. Expansion in wheat area has declined from 1.7% per year in the decade of the 1950s to under 1% currently. An increase of 0.8% per year to 2000 may be optimistic. Some of this will occur in irrigated areas. However, FAO's projected increase in irrigated area of 1.2% per year now appears optimistic: the cost of developing irrigated land is rising rapidly, and some existing schemes may not be sustainable due to salinity, waterlogging, or declining water tables.

There is cause for optimism in maize production, while increases in wheat will be more difficult to achieve.

With an annual area increase of only 0.8%, wheat yields will have to rise by 2.2% each year to meet the projected production growth rate of 3%. Yet semidwarf wheats are already sown to the bulk of the wheat area and fertilizer applications are relatively high on much of the irrigated area. There is scope for improving crop management on much of the developing world's wheat area, sufficient even to enable the needed growth rate in yield. To do this, however, will require significant modifications in strategies toward a broader range of yield increasing practices.

Use of technology A number of economic trends are likely to affect the profitability and efficient use of improved maize and wheat technologies by farmers.

Input prices No major changes in input prices are foreseen to 2000. Even so, we are mindful of increasing long-term real prices of energy and the need to seek energy-efficient agricultural technologies. Moreover, irrigation water will become more scarce as the development of new supplies slows, fossil water supplies are exhausted, and nonagricultural land use increases.

Many Third World farmers will be caught between rising costs and declining prices for cereals, requiring more efficient use of inputs and technology.

Imports of maize and wheat by developing countries will continue to grow.

Come 2000, South Asia will still host the largest number of malnourished people, though Africa will suffer the largest relative increase in their ranks.

Producer prices Real prices received by maize and wheat growers are likely to fall in some developing countries, following trends in world prices for cereals, policy reforms that align domestic and world prices, and as cereal self-sufficiency in some countries puts pressure on domestic prices. Many Third World farmers will thus be caught in a cost-price squeeze that will require more efficient use of inputs and technology.

Commercialization of small-scale farming By 2000, a great many more farmers in the developing world (less true in sub-Saharan Africa) will be linked to the national economy through improved infrastructure and communications. This will encourage greater use of purchased inputs and increased crop specialization. Farmers will therefore require improved technical information and greater managerial skill as agriculture becomes more science-based and commercialized.

Population pressure Almost everywhere additional population pressure on land resources will accelerate the trend toward greater cropping intensity. At the same time, maize and wheat production in some regions will be forced increasingly into marginal areas. Trends toward increased intensification of land use, along with greater crop specialization, pose major challenges for developing sustainable agricultural systems.

Given the rapid growth of developing country wheat production in the past, the already widespread use of improved technologies, the drag that current policies impose on further production increases in wheat, and the opportunities that seem to be at hand in maize, we project faster rates of increase in maize than in wheat production to 2000. Even so, for both crops we forecast a continuing growth in the imports of developing countries.

Malnourishment The largest number of malnourished people will continue to be concentrated in South Asia, where grain stocks exist but many people lack the means to purchase food. The largest relative increase in the malnourished will be in Africa due to inadequate food supplies and low incomes. In sub-Saharan Africa, where over 90% of all maize is used as food, per capita production continues to decline. This decline is particularly serious given the inability of many African nations to compensate through imports. A growing maize production deficit is also likely in other developing regions, especially in Asia, but the cause will be rapidly rising demand for feed grains. It is also likely that much of that deficit will be overcome through imports. As for wheat, the level of self-sufficiency will not change significantly. It is likely that the most rapid growth in wheat imports will occur in Africa.

Implications for CIMMYT These projections imply no global food crisis to 2000. In that context, if increased wheat and maize production are to contribute to alleviating hunger and malnutrition, productivity increases must be aimed at regions of chronic food deficits and, as well, at regions and countries where

maize and wheat are important sources of income for poor producers or are significant in the diets of poor consumers. This implies that we should give greater weight to research that will benefit the poor, relative to research that will increase production without regard to distributional consequences.

CIMMYT must give even greater weight to research that benefits the poor.

The Strength of National Agricultural Research Systems

■ Strategic planning is client-driven, and we have gone to considerable lengths to gain an understanding of the capabilities and needs of our immediate clients, the publicly funded maize and wheat research programs in developing countries. National agricultural research systems include private sector institutions as well, and these entities often find CIMMYT's products and services useful. We believe that stronger national systems contribute more effectively to opening options to the poor. Some of our activities offer system-wide benefits and, to that extent, we think of national systems as our clients (see box, *Relationships with National Programs and the Private Sector*).

National programs in developing countries are our primary clients.

We are most interested in the research capabilities of national programs in germplasm improvement, crop management, and economics. To gauge overall strength, we first conducted a survey among experienced CIMMYT regional staff, and augmented their views through a similar survey among national program representatives. Research programs were ranked according to their present capabilities and those expected by 2000.

The present analysis considers only two aspects of the surveys, germplasm improvement capabilities for maize and for wheat. Rankings for germplasm improvement correlate highly with those for crop management, albeit crop management capabilities lag well behind expertise in working with

Relationships with National Programs and the Private Sector

CIMMYT is committed to expanding the options open to resource-poor farmers in developing countries, and it executes this commitment through national agricultural research systems, especially the publicly funded research programs that we view as our primary clients.

We see private companies as important components of national systems as well. Private-sector companies, especially those dealing with seed, are alternative suppliers of improved germplasm, and they, too, open options

for farmers. To the extent that our objectives coincide with theirs, we see advantage in providing germplasm to them on request.

In meeting seed requests from the various groups that comprise national systems, we give first priority to publicly funded national programs, followed by private cooperators within client countries, national private seed companies, and multinational private seed companies. When national programs request it we channel our deliveries to private companies through them.

Stronger national research systems contribute more effectively to creating options for the poor, and we see their research capabilities improving steadily, albeit not uniformly.

germplasm. Thus, national programs strong in germplasm improvement are also relatively strong in crop management. Too, the strongest maize and wheat programs tend to be found in the same countries. Though we limit ourselves to an analysis of current rankings for germplasm improvement, these assessments can be projected forward in time and to other areas of competency with some confidence.

The scale used to assess national program capabilities was as follows:

- 1) A full-fledged program capable of developing quality varieties from the crossing-block onward. Staff and support are adequate.
- 2) Same as ranking 1, but program lacks experience or key support to deliver quality varieties on a continuing basis for all major environments.
- 3) The program is capable of developing useful varieties but staff or support are limiting relative to rankings 2 or 1.
- 4) Even the development of varieties requires outside professional support.

About half of all Third World maize is produced by the four countries that have the strongest maize research programs.

Rankings for developing country maize programs A summary of key characteristics of the different ranks of maize programs is presented in Table 3.4. The production figures used in this table do not include temperate maize, which is largely found in Argentina and China. It is omitted from our

Table 3.4. A profile of developing country maize research programs.

	Program rank (germplasm improvement capacity)			
	1	2	3	4
Number of programs	4	17	19	14
Percentage of total maize production ^a in this rank	49.7	33.8	12.4	2.5
Percentage of maize production ^a in this rank in:				
Low-income countries	16	44	31	100
Lower/middle-income countries	8	53	61	0
Per capita utilization ^b (kg/yr)	144	73	84	48
Yield (t/ha) ^b	1.9	2.2	1.2	0.9
Per capita income (\$US)	1,462	606	694	235
Percentage labor force in agriculture	40	66	59	79

a Not including temperate maize.

b Including temperate maize.

analysis because developed countries are such strong alternative suppliers of temperate maize germplasm.

The majority of the developing world's maize is produced in countries whose national research systems have the highest ranking. National programs with lower rankings represent correspondingly lower proportions of production. Per capita maize utilization also tends to be higher in those countries that are highly ranked, with India and Brazil being the notable exceptions.

Measures of poverty show an opposite relationship. Countries with lower ranked maize programs tend to be poorer, with lower per capita incomes, a higher proportion of the labor force in agriculture, and lower maize yields.

Rankings for developing country wheat programs The same analysis is presented for wheat programs in Table 3.5. The production figures used in this table do not include winter wheat, which is largely found in China and Turkey where strong national programs can combine with developed country specialists to satisfy much of the need.

As for wheat production, more than half comes from the four developing countries with the strongest wheat research programs.

As with maize, the majority of Third World wheat is grown in countries whose national research programs have the highest rankings. Other relationships that hold for maize, however, are not in evidence for wheat. Per capita income tends to be higher in countries with lower ranked programs, and the proportion of the labor force in agriculture tends to be lower. Per capita utiliza-

Table 3.5. A profile of developing country wheat research programs.

	Program rank (germplasm improvement capacity)			
	1	2	3	4
Number of programs	4	8	25	5
Percentage of total wheat production ^a in this rank	54.4	26.5	17.4	1.7
(Percentage including winter wheat)	(66.7)	(20.5)	(11.8)	(0.9)
Percentage of wheat production ^a in this rank in:				
Low-income countries	90	39	27	2
Lower/middle-income countries	4	27	24	0
Per capita utilization ^b (kg/yr)	71	182	142	67
Yield (t/ha) ^b	2.2	1.8	1.9	3.7
Per capita income	370	1,197	1,420	8,692
Percentage labor force in agriculture	68	41	48	48

a Not including winter wheat.

b Including winter wheat.

tion is not related to program rankings, nor is there any strong relationship with respect to wheat yields.

Because national programs have different capabilities, CIMMYT must offer a range of products and services.

The question is how to balance the offering.

Implications for CIMMYT First, these rankings argue that we should be able to offer different products and services to different types of national programs. The rankings help us to identify the size and location of the demand for our outputs. The fact that there are significant differences between the rankings of maize and wheat national programs serves notice that our program-level strategies may well differ.

We believe that national programs will continue to improve in their ability to conduct research and to provide certain types of training for themselves and, eventually, for others. We do not expect, however, that national programs will progress uniformly during the next 12 years. Indeed, national program representatives have indicated that they themselves do not expect to progress uniformly, a finding reinforced by self-assessments made during a series of three regional meetings with national program colleagues (held in February, 1988).

For both maize and wheat, the majority of national programs are small and poorly developed, and represent a relatively small portion of the crop. We seek an appropriate balance between the attention we give to the majority of the crop (for the most part through larger, more advanced programs) and the attention we give to the majority of programs (even though they affect a minority of the crop).

Changes in Science

■ Because research is CIMMYT's primary enterprise, we must assess likely changes in the conditions under which it is conducted. We must also consider the speed with which results arising from basic research in developed nations will be diffused to developing nations, and to consider the capacity of national programs to use those results.

Where research is done, who controls access to outcomes, and the manner in which results are shared will shape the environment of science well into the next century.

Changes in the environment of science Present allocations of research resources, coupled with scientists' intuitions, provide a general guide to the future environment of science. While details remain shrouded, we can confidently predict that the rate at which change occurs will continue to accelerate. And it is important to note that our own research will bring about changes in the scientific environment, especially that of developing countries.

The location of basic and strategic research Basic research is becoming more expensive and more demanding in terms of trained personnel, the timely supply of reagents, and the maintenance of expensive and delicate equipment. By implication we expect that such research will be increasingly concentrated in

developed countries, and that they will establish the basic and strategic research agendas. With some exceptions, developing countries generally will remain importers and modifiers of advanced technology.

Intellectual ownership The direction of research and access to results will be increasingly affected by issues of political and intellectual ownership. Access to the results of certain classes of research will become more restricted. For example, if research funded by the private sector succeeds in transferring highly effective alien genes for stress tolerance to maize, it seems likely that neither the techniques nor the germplasm will be freely available to CIMMYT or its clients in a reproducible form. International legal sparring over private ownership of germplasm will continue throughout the next decade. On the positive side, however, it appears likely that in the high yield potential areas of more advanced developing countries, agribusiness will assume some of the public sector's functions, especially for maize.

Capacity to share information The ability to communicate and store large quantities of information of all types will continue to expand rapidly (see below). By 2000, global information exchange will be comparable to that available today in developed countries. Here too, however, issues of intellectual ownership and nationalism may impose restrictions on the international movement of information.

Important outcomes of science Computing and biotechnology are two areas of science in which rapid changes are taking place. Both should provide new opportunities that will have far-reaching effects on almost all of the research in which CIMMYT engages.

Computer technology Improvements in computing and data management technology will vastly augment our ability to store, access, distribute, and process large quantities of information at low cost, and could significantly accelerate the rate of technological change in all countries. Powerful microcomputers with simplified operating environments will become more common in national programs during the next decade. Consequently, we will need to devote more attention to the quality, analysis, organization, and management of the data we routinely collect.

Major developments are expected in the next few years in expert systems, particularly those that deal with statistical analysis. These tools will enhance the capacity and efficiency of researchers to design and analyze experiments. Concomitantly, we expect a growing demand from national programs for software used to generate improved designs.

New computer and data management technologies will affect much of CIMMYT's research, and the rate of change in this area will likely outstrip the capacity of many national programs to take advantage of new developments.

While current breeding techniques will remain paramount to 2000, biotechnology research will provide new techniques that will increase efficiency and add to genetic variability.

As high-capacity desk top computers become more common, we expect to see an increase in both the number and predictive capability of computer-based models. These will serve to integrate information from many different disciplines, and will include physiology-based crop production models sensitive to environmental and genetic variability. Epidemiological models of fungal diseases using remote sensing data as inputs are expected to serve as increasingly reliable adjuncts to disease surveillance.

In developing countries, however, advances in information storage, retrieval, and distribution will likely outpace the capacities of many national programs to analyze and interpret data, and to provide personnel trained in the use and service of the associated equipment.

Biotechnology While our knowledge of genetic and biochemical processes in plants will no doubt grow considerably due to biotechnology research, major near term payoffs for applied plant breeding are less certain. We are convinced that current breeding techniques will remain the most important methods of crop improvement and genetic manipulation to the year 2000, with biotechnology research providing important new techniques that will increase the efficiency of selection and the genetic variability available to the breeder.

Some recently developed techniques will prove useful to CIMMYT's breeding program. For the immediate future we see utility in:

- *Restriction fragment length polymorphisms (RFLPs)* These genetic probes offer great promise and we are moving rapidly to apply them. Longer term uses will include genome mapping of CIMMYT's crops, the identification of loci governing agronomically important traits, and the identification of heterotic groups for maize. RFLP technology will also offer cost-effective, precise testing for the presence of genes that control specific traits for which field selection is difficult or inconclusive.
- *Tissue culture* Regenerating plants from tissue calli growing in special media can be applied to plant breeding in various ways. Breeders can select for specific traits, such as resistance to herbicides, heat stress, salinity, and disease toxins; somaclonal variation (genetic variation induced by the tissue culture process) may provide new sources of genetic variability; embryo rescue techniques can recover rare wide-cross hybrids; the introgression of alien genomes into cultivated species (e.g., *Tripsacum* into maize) may be accomplished more rapidly than through backcrossing; and the rapid development of homozygous lines in small grains.

Further into the future we see possibilities through:

- *Disease and growth regulator diagnostics* Monoclonal antibodies and complementary DNA probes can detect the presence and concentration of pathogens (particularly viruses and mycoplasmas) in plants and in insect vectors, and can be used to locate and identify virulence genes in pathogens. The precision, rapidity, and sensitivity with which pathogens can be detected and diseases can be diagnosed are increasing. We are also learning more about host plant interactions. These advances, when combined with epidemiological studies and disease loss assessments, will enhance our understanding of the mechanisms and durability of host resistance genes. The ability to easily and precisely identify pathogen races will be useful in developing durable disease resistance and in monitoring disease resistance on a global basis.
- *Genetic transformations* We expect that transfers of single genes governing important traits and of regulator genes that turn existing genes on or off will be accomplished in maize and wheat within the next ten years. However, most traits of interest to plant breeders are controlled by multiple genes and we see such complex gene transfers as further in the future. The limiting factor in multigene transfers most likely will not be the technical ability to do them, but rather the level of understanding of genetic, biochemical, and physiological interactions required for their effective use. Also, problems with the regeneration of whole, fertile plants from protoplast, cell, or callus culture may hinder the practical utility of gene transfers. Still, multigene transfers may enable breeders to significantly improve yield potential stability, efficiency of biomass production, and biological nitrogen fixation.

Most traits of interest to plant breeders are controlled by multiple genes, and we see such complex gene transfers as further in the future.

Because of the complexity, cost, and rapid pace of biotechnology research, CIMMYT will not seek to be a leader in basic research in this field. We will, however, establish and maintain close contacts with other institutions engaged in biotechnology research, monitor developments, and be ready to apply proven techniques appropriate to our research. To date, we have helped initiate a maize molecular biology network of North American and European institutions, we are collaborating with the Mexican biotechnology laboratory (CINVESTAV) on an RFLP project, have begun construction of our own molecular biology laboratory, and are moving forward with a project to map the wheat genome.

CIMMYT will not lead in basic research but will be at the forefront in applications.

Most biotechnology research is focused on the agricultural problems of developed countries. We will strive to stimulate research in areas appropriate to developing country agriculture and concentrate our own efforts on adapting developed country technology to those needs. The involvement of national programs in biotechnology research is expected to increase dramatically by

2000. Unfortunately this will likely come at the expense of research in applied plant breeding and production agriculture, thus posing potentially serious problems for agricultural development. The Center will occupy a rather unique position relative to biotechnology research, providing expertise in its application to plant breeding, training others in the skills needed to apply it, and making cost- and time-saving techniques widely available.

We will develop and provide expertise in the application of new techniques to plant breeding; we will also train others in their application and ensure availability to national programs.

Other areas of science Several other rapidly developing areas of science may impinge directly on our work. We expect considerable progress in quantitative genetics, for example, as well as in techniques for the introduction of alien DNA into maize and wheat genomes. Relative to wheat breeding, biomass production will become a more important objective, and improvements in gametocides and male sterile systems are anticipated. In maize breeding, we foresee significant developments in apomictic systems for maize hybrid seed production. And we expect improvements in the efficiency of multilocation testing for both crops.

Significant advances are expected in remote sensing techniques, in the use of satellite data, and in aerial infrared photography, all of which will enhance modelling, mapping, and epidemiological work. So, too, will we see new statistical methods that reduce experimental error and improve our ability to make performance predictions.

Implications for CIMMYT The future environment of science is largely unpredictable. Decisions as to what research is done, who does it, and levels of funding are increasingly influenced by non-scientific considerations, affecting the scientific environment in ways difficult to foresee. In any event, the precise prediction of future trends in science is not the essential issue. Rather, for us it is the need to be sufficiently sensitive to recognize, and flexible enough to integrate, worthwhile new developments; we will actively pursue ways to augment these qualities.

Alternative Sources of Supply

■ CIMMYT recognizes that several of its products and services are or could be provided by other national or multinational agencies, both public and private. The likely trends in these alternative sources of supply were important in assessing our comparative advantage to produce and deliver various outputs.

Alternative sources of supply were divided into several categories:

- Other international agricultural research centers
- Regional research centers or networks (e.g., the Southern African Center for Cooperation in Agricultural Research, SACCAR)
- Bilateral and multilateral donor and technical assistance agencies

- Private-sector research organizations, both multinational and national
- Public-sector research organizations in developed countries
- Public-sector research organizations in developing countries (i.e., national programs)

Several of CIMMYT's current products and services are or could be provided by others.

Clearly, as national programs grow stronger they become an increasingly important factor in the array of alternative suppliers of the Center's offerings. Table 3.6 summarizes our view of likely trends relative to other alternative suppliers to 2000.

The private sector The most important changes in alternative sources of supply are expected to result from growing private-sector involvement in agricultural research. In the 1980s, multinational and national companies in the Third World have rapidly increased their investments in agricultural research and in seed multiplication and marketing, especially of maize hybrids. These investments will result in an increasing proportion of maize area in many major maize-producing countries being planted to hybrids developed by private companies. The initial impact (which is already well underway in many countries) will be on favored environments with relatively high yields, where payoffs to hybrid seed are highest. To some extent the initial beneficiaries in these environments will be larger scale farmers.

Private-sector involvement in agricultural research, especially in hybrid maize development, will continue to increase in developing countries.

For the next decade, CIMMYT will remain the major international source of maize germplasm for tropical areas and, to some extent, for subtropical areas. Temperate maize germplasm will continue to originate in developed countries,

Table 3.6. Trends among alternative suppliers of some CIMMYT products and services to 2000 (++ Strong increase; + Increase; — Decrease).

Product/service	Private sector		Other IARCs/ regional centers	Development agencies, multilateral and bilateral	Public sector, developed countries
	Multi-nationals	Developing countries			
Germplasm (maize)	++ ^a	++ ^a	+		—
Germplasm (wheat)	+		+		
Crop management research	+ ^b	+ ^b	+ ^b	+ ^b	
Research techniques	++		+		
Training				+ ^c	+ ^c
Consulting services			+	+	+
Information			+	+	

a For favored areas. Germplasm for tropical and subtropical areas will, however, often originate from CIMMYT.
 b Greater for adaptive research.
 c General training.

usually from private companies. As in the past, these companies will utilize our germplasm as source materials for tropical and subtropical products.

Public sector national programs will need to evolve in ways consistent with the growing importance of the private sector. The evidence to date suggests that, where public sector institutions seek a complementary rather than competitive relationship with the private sector, the overall productivity of the research system is enhanced.

For wheat germplasm in developing countries, participation of the private sector is unlikely to be important unless significant breakthroughs occur in breeding hybrid wheats or developing countries adopt and enforce plant varietal rights. In our view neither event is likely by 2000.

The private sector will also play a greater role in crop management research in both maize and wheat, particularly in the use of chemical inputs. Again, these efforts will generally focus on better environments and, within these environments, on larger farms.

ICARDA and IITA will serve as alternative suppliers of certain CIMMYT offerings.

Other suppliers Some change is foreseen among other suppliers of the Center's products and services. The International Institute of Tropical Agriculture (IITA) and the International Center for Agricultural Research in the Dry Areas (ICARDA) will increase their contributions to crop management research and to germplasm improvement for selected regions. In particular, IITA will take on the CGIAR responsibility for maize improvement in western and central Africa, with CIMMYT working through IITA. Regional research centers will also be involved in crop management research focusing on maize and wheat. Through cooperative and networking arrangements, the work of those centers can complement our global efforts.

And as national programs grow stronger, they become increasingly important both as potential alternative suppliers and as producers of products and services that complement the work of the Center.

We anticipate that development agencies (both multilateral and bilateral) will play a greater role in adaptive crop management research, general agricultural policy analysis, and in providing information and training related to crop management research and consulting services to national programs. Developed country institutions are likely to offer more specialized training and degree programs and will reduce their offerings in general plant breeding and agronomy.

National programs of developing countries comprise yet another source of supply for our products and services. These programs already contribute improved germplasm to the international nursery systems managed by CIMMYT. Some have expressed interest in doing more in the future, including taking on primary responsibility for certain types of training and for particular classes of germplasm.

Implications for CIMMYT Overall, the worldwide trend toward privatization of research will have significant implications for us in the years ahead. Third World consumers and producers will benefit from the trend if complementary relationships are developed between private and public sector institutions. We will need to monitor these changes in institutional arrangements, including the legal aspects of intellectual property rights. We will also want to consider registration of our improved materials, which would ensure access by developing countries (without royalties). Furthermore, we could offer to exchange our materials with private sector and/or developed country patent holders on other materials or life forms of interest to our clients. Finally, we will seek creative ways to decentralize some of our activities in conjunction with selected national programs.

The Physical Environment

■ Several aspects of the physical environment may have a significant bearing on the Center's research agenda and operational strategies, and therefore require periodic monitoring to help ensure the relevance of our work.

Weather patterns Recent analyses of climatic change in the United States suggest that the period from 1958 to 1982 enjoyed the most favorable weather for maize production of any 25 years on record. Because of the cyclical nature of weather patterns, a period of drought and high temperatures in the US Corn Belt is predicted for the early 1990s. Although it is not clear what effects this may have on weather experienced elsewhere, it could clearly have an important effect on global grain prices.

Crop intensification Many longer term changes expected in the physical environment will result directly from increasing population pressure, mostly in the Third World. From 1950 to 1975 the global average area of cropland per person fell from 0.24 ha to 0.18 ha, and is expected to drop to 0.13 ha by 2000. This will intensify the use of land already in agricultural production and promote the expansion of agriculture into less favored and often more fragile environments. Such a forecast raises questions about the long-term sustainability of agricultural production.

Crop intensification means less time for land to lie fallow. When this occurs, natural nutrient recycling from crop wastes is reduced, soil compaction, erosion, and drainage problems increase, soil organic matter is lost, pests and diseases build up, and demand on water resources increases. Under these circumstances, higher yields are normally obtained by more widespread and frequent application of water and agrochemicals; the latter have potentially serious implications for contamination of ground and surface water reserves.

Shifting weather patterns, increasing crop intensification, the loss of arable land, a slowing in irrigation, and other long term environmental changes may have important affects on CIMMYT's research agenda.

Current trends imply greater commitments to breeding for stress tolerance, yield stability, and input-use efficiency, as well as an orientation to our crop management research that favors sustaining agricultural resources.

Loss of arable land It is estimated that each year waterlogging and salinity are rendering unproductive some 1.0-1.5 million hectares of cropland, and that erosion is responsible for the net annual loss of some 26 billion tons of topsoil. Desertification is removing a further 6 million hectares of agricultural land each year. The spread of urban areas is also steadily and significantly reducing cultivable area. Expansion in area, where still feasible, will almost always be onto land that for a variety of reasons has not been brought into use previously. Such land is often marginal for crop production.

Irrigation In 1980, irrigated land area was projected to rise 40% by 2000. Such an increase would have accounted for almost 50% of the additional food production required by the turn of the century. To date, the actual increase in irrigated land has fallen well short of this prediction, and a number of irrigation schemes that depend on fossil water will probably be inoperative by the end of the millennium.

Other long-term trends The effects of other long-term trends in the environment are less clear. The global increase in carbon dioxide is predicted to lead to an increase in the earth's average temperature of 0.3-0.9°C by 2000, a circumstance that is unlikely to have much direct effect on the agriculture of tropical regions. Higher atmospheric carbon dioxide levels will heighten the water and nutrient use efficiencies of most crops, resulting in slightly higher yields in the future. The recent decline in the protective layer of ozone in the upper atmosphere near the South Pole, if it spreads to other areas, could result in significant direct crop damage and in higher rates of natural mutation in agricultural crops.

Implications for CIMMYT The proportion of crop environments characterized by nutrient, water, or temperature stresses appears to be rising. At the same time, such resources as water and nutrients are becoming either more scarce or more expensive, requiring improved efficiency in their use. Both trends imply an increased commitment to breeding for stress tolerance, yield stability and input use efficiency within our germplasm improvement programs, and an increased commitment to sustainable production systems within our crop management programs.

Planning aims to enhance the decision making process of an organization. Our planning framework, strategic planning, is anchored in the future and makes explicit the assumptions and criteria that affect decisions. It provides a clear rationale for resource allocations and a framework for fostering congruency between plans and the unfolding future.

Our first step in planning, discussed in the previous chapter, was to identify the most relevant dimensions of our future environment, including precisely who our clients will be. We deferred until now a discussion of the policies and guidelines of the CGIAR. This chapter relates specific decision criteria to those concerns.

The CG's primary concerns are an emphasis on the poor, an efficient use of resources in meeting their needs, sustaining the productivity of resources used in agriculture, sub-Saharan Africa, marginal lands, and a growing emphasis on basic and strategic research. From these general concerns we formulated a tentative list of criteria and then went on to identify those most relevant to our decision making. These are briefly discussed below, for the most part ordered in terms of their relationship to System concerns. Their application is treated in Chapter 5.

The criteria we use to establish priorities and allocate resources all rest upon concerns of the CGIAR.

Expected Economic Returns

■ We recognized the overriding desirability of being efficient in reaching the poor. Being less efficient means reaching fewer poor or reaching them with less. Thus, we needed a measure of the utility that each of our actions might bring to the poor. Well-known conceptual difficulties and data limitations led us to start with a measure of the economic benefit that each of our actions might induce. We then modified those indicators according to the estimated promise for the poor and, beyond that, according to the other concerns of the CGIAR.

The potential economic benefit of our various activities provided the starting point of our analysis. These indicators were then modified according to CGIAR concerns.

Our first step was to define the various products we might deliver, for example improved maize for specific lowland tropical areas. We then estimated the current economic value of each, forecast the gains that might be made through the allocation of a defined bundle of resources, projected the likely price and cost changes that might occur over the planning period, and examined the likely consequences that progress on one product might have for another. This gave us a measure of the likely economic returns to potential activities. Clearly, some activities were more and some were less amenable to evaluation.

Impact on the Poor

■ CIMMYT's mission explicitly recognizes the poor of developing countries as the intended beneficiaries of its work (see box, *Reaching the Poor Through Agricultural Research*). New maize and wheat technologies may have greater impacts on the poor if they:

- Address the needs of poor producers, especially those concentrated in particular agroclimatic environments
- Reduce the price of food to poor consumers
- Promote greater employment of rural labor in production
- Lead to significant growth in other sectors of the economy (especially labor-intensive sectors)

Food Versus Feed

Of the criteria used, six relate to efficiency, four to concern for the poor, one to sustaining natural resources, and one to sub-Saharan Africa.

■ Related to the poverty issue, and of particular importance to maize, is the question of food use versus feed use. More than half of all maize produced in developing countries is currently used for feed. By 2000, feed use is expected to grow to some two-thirds of total production.

Because feed goes to producing animal products and these are less prominent in the diets of the poor than are cereals, some argue that the poor will benefit relatively more from added food grain production than from enhanced feed grain production. Our examination of the argument suggests that, while valid, its implications for weighting in our decision making process are small relative to the weight we give to poverty itself.

Stability of Yield

■ Also related to concern for the poor is the concept of yield stability. Resource-poor farmers tend to be more averse to taking risks. For that reason, stability is featured in much of our work—in judging germplasm, in formulating crop management strategies, and in orienting our direct work with national programs.

Human Nutrition

■ This criterion is closely related to concern for the poor and we recognize its role by ensuring that our germplasm products meet conventional minimum levels of nutritive value.

Alternative Sources of Supply

■ This criterion emerges from the concern for efficiency. CIMMYT is part of a wider international research network that includes other international centers, development agencies, and the public- and private-sector entities that comprise national research systems in developing and developed countries. Careful attention must be given to the question of which institutions in the total research system have the advantage in providing specific products and services. Hence, an important criterion for establishing our priorities is the extent to which the Center is preferred over other suppliers of a given product or service.

As a corollary, there are complementary suppliers who can enhance our efforts. For example, the International Rice Research Institute (IRRI) shares our interest in research on sustaining the resource base of the rice/wheat systems of Asia. Their research on rice in that system complements our research on wheat, making both efforts more valuable.

Strengthening National Programs

■ Relationships among CGIAR centers and national programs are complex. In some instances, national programs might serve as alternative sources of supply for the products and services delivered by the centers. Indeed, the System is challenging its centers to decentralize toward national programs

Reaching the Poor Through Agricultural Research

One of the major challenges in reaching the poor through agricultural research is that there are many classes of poor. They experience a wide range of problems and conditions; the impact of agricultural research decisions on various classes is not always clear; and in more than a few instances the interests of different classes compete. An additional challenge for CIMMYT is that the delivery of its products to the poor must be mediated by national research and extension systems, each responding to its own policies and priorities.

Perhaps the principal debate affecting the formulation of our strategies concerns the relative importance of producers and consumers. It can be argued that consumers have taken precedence in the past, especially when low global food availability and rising food prices constituted the major challenges. The progress in keeping food supplies in line with population growth indicates the success of that strategy. At the same time, there is ample evidence of an urban bias in many agricultural development policies and a lack of attention to the rural poor. Although improving the livelihood of small producers and agricultural laborers is receiving greater emphasis, they still constitute the forgotten sector of many nations.

We will continue to contribute to national capabilities for maintaining adequate food supplies for consumers. Although there are many aspects of rural poverty that we simply cannot address, we will devote particular attention to production technologies appropriate for small farmers.

In many instances there will be little conflict between these strategies. Increased food supplies must come from the small farm sector since it represents the vast majority of agricultural land and resources in most developing countries. In other instances, national programs must make difficult choices between favoring the production of cheap food by large-scale producers in favored environments and supporting the development of the small-scale sector in less favored environments.

In assessing our own priorities, we will give extra weight to the rural poor. In part, this is an effort to redress the balance, as earlier work favored consumers. Improved technologies will focus on adding to the incomes of farmers and laborers. Beyond this, however, this stance is encouraged by the growing evidence for agriculture as an engine of growth for national economies.

The potential of strong national programs to both substitute for and complement our work leads to some ambiguity in assessing our relationships with them relative to weaker programs.

those activities currently undertaken by the centers but in which national programs can match costs, quality, and certainty of delivery. This challenge is consistent with the System's concern for efficiency in resource use. Stronger national programs are the most likely to play this role. On the other hand, stronger programs are also more likely to capitalize on CIMMYT's research efforts than are weaker programs, thereby enhancing the returns to our investments in research.

There is also the CG's interest in providing direct support to national programs, particularly the less advanced ones, so that they might be more effective in working with farmers. This interest is complicated by the fact that returns to resources invested in direct support to national programs are heavily influenced by factors not amenable to CG influence (see Chapter 5). Thus, some ambiguity results in assessing relationships with stronger national programs relative to weaker ones.

Operational Scale

■ This criterion also rests on the concern for efficiency. We believe that total returns to increased scale level off rapidly in our work, especially in plant breeding. In other words, the extra benefits coming from additional breeders working on the same set of research problems (i.e., the same mega-environment) decline quickly. This perception has implications for the relative resource allocations between maize and wheat.

Minimum Critical Mass

■ No activity should be undertaken without at least enough resources to produce a product that has some current value. This is the idea of "minimum critical mass." Beyond that, it is also necessary for an activity's expected future value to exceed the potential return that could be earned if resources were used in some other way.

"Upstream" Research

■ The System advocates that the international centers move "upstream," away from applied/adaptive research and toward more strategic activities. As we see it, this counsel rests on concern for efficiency. One argument holds that new tools coming from basic and strategic research will reduce the cost of delivering the current product mix. This justification is fully consistent with our own concern for efficiency. Given these considerations, we judge our movement upstream in terms of potential contributions to expected returns.

Sustaining Natural Resources

■ In many areas of the world, population pressure and crop intensification have placed serious pressure on soil and water resources. These forces jeopardize the productivity of such resources over the long run. Our concern must be to balance the demands of the present and those of the future, hence

Much of our current work rests on our concern for sustaining the productivity of natural resources, and we see opportunities for even greater emphasis in the future.

our interest in sustaining the productivity of resources committed to agriculture. CIMMYT's commitments to germplasm conservation, to disease resistant materials, and to training with a natural resource maintenance perspective are consistent with the concern. We see, however, the possibility of even greater emphasis, e.g., through innovative research on the management of the critically important rice/wheat rotation in the Asian subcontinent. We recognize that work in this arena carries with it considerable risk. Even so, the resource allocations described in Chapter 5 reflect our interest in extending the Center's role beyond its current activities.

Sub-Saharan Africa

■ The CG has a special concern for sub-Saharan Africa. Africa is so notably poor that, on the face of the matter, our emphasis on benefiting the poor in itself implies an emphasis on Africa. Yet there is a sense that the System has brought less to Africa's poor than to the poor of other continents. There is, then, a "catch-up" factor that we recognize in planning for the future by giving more weight to the poor of Africa than to those of other continents.

Criteria Summarized

■ Briefly, then, 12 interrelated criteria helped establish our priorities for activities. As we see it, six of these emerge from the System's interest in efficiency, four rest on its concern for the poor, one relates to sustaining natural resources, and one to the special needs of sub-Saharan Africa. Two additional concerns of the CGIAR, perhaps conspicuous by their absence here, have to do with marginal lands and the role of women in agriculture. While acknowledged as important, we did not consider them as separate criteria affecting our overall resource allocations. See the accompanying boxes, *Marginal Lands and CIMMYT's Research Agenda* and *Perspectives on Women in Agriculture*, for more discussion.

We use these criteria to establish priorities and allocate resources, first at the CIMMYT-wide level, then among Program-level activities, and finally within the context of individual projects.

Not all of the criteria outlined above will apply to every decision and the importance they assume may, in some cases, vary. They do, however, constitute the primary considerations that CIMMYT decision makers use in allocating resources among competing activities and projects. Furthermore, they are used at several levels of decision making: first at the CIMMYT-wide level, such as in decisions about allocations between maize, wheat, and economics; then within the context of the Center's various programs, such as in the Maize Program's allocations among major activities; and ultimately within the context of individual projects, such as the spring bread wheat program's allocations among mega-environments. Their application underlies the discussion of Chapter 5.

***Marginal Lands and
CIMMYT's Research
Agenda***

Growth in demand for food has encouraged agriculture to expand into areas less suited to production, and there is no reason to believe that this trend will be reversed in the near future. These environments are characterized by shortages of moisture, temperature extremes, diseases and insects, deficiencies or toxicities of nutrients, flooding, and salinity. In their more extreme form these environments are called "marginal." We consider marginal environments to be those areas in which yield of the target crop is reduced to 10-40% of the yield potential, as determined by the amount of radiation received over the normal length of the growing season.

Our discussion of marginal environments considers only abiotic stresses; even so, they represent a large proportion of agricultural land. In response to a questionnaire, national program officials estimated that about half the maize and wheat in their countries suffers from abiotic stresses. They noted that although their current research budget allocations might not adequately reflect the importance of

these environments, additional resources will be devoted to them in the future.

This increased emphasis on marginal lands arises from the effort to sustain the natural resources in these areas, and from the probability that the problems of poor producers are more acute in less favored environments. Although resource-poor producers are found in all production environments, the human consequences of variability in production may be more severe in marginal areas.

The problems of marginal environments can be addressed through research on crop improvement and crop management. We will devote resources to those problems, taking into account the amount of production they represent and the implications of such work for sustaining resources, for stability, and for poor producers. We will, however,

Perspectives on Women in Agriculture

CIMMYT recognizes the important role played by women in agricultural production and processing in most developing countries, and we reflect this role in our work in on-farm research. We have developed research methods for sensitizing researchers to the needs and circumstances of target groups of farmers, and organized workshops and training programs in the use of these methods. On-farm research calls for the delineation of homogeneous groups of farmers, referred to as *recommendation domains*, for targeting technological innovations. To the extent that these groups are made up of female farmers, the recommendation domain concept correctly identifies their special technical needs.

Through these methods, on-farm research addresses the relationship between the role of women and the generation of acceptable technologies for diverse situations. Examples include: the relationship between women's time and food processing in Ecuador; the impact of combine harvesters on female labor markets in Pakistan; the research needs for intercropped maize, the main method of maize culture for women farmers in central Ghana, and the design of weed control technologies in terms of women's time allocation between farm and non-farm activities in Swaziland and Zimbabwe. An adoption study in Ghana showed, as one would expect, no difference between the rate at which suitable maize technology was adopted by men and women farmers.

Although progress has been made in identifying the role of women in maize and wheat production and

processing and in designing technology accordingly, we recognize that more needs to be done. Greater attention will be given to intra-household issues and decision making within the household. Many households in developing countries are composed of different subunits for production, consumption, and investment. Intra-household relations may also regulate family members' access to resources and hence, farming decisions. For example, household members' involvement in nonfarm activities may strongly influence farmers' acceptance of new technology. Through its work in on-farm research, our regional economics program in southern Africa has given special emphasis to these issues.

The Center's training programs now give greater emphasis to the role of women in farming. For example, the Regional Training Workshop on On-farm Research held annually at the University of Zimbabwe uses as its field site a communal area with a high percentage of households headed by women. This helps emphasize that women farmers might benefit from different recommendations than men farmers. In another dimension, the number of female participants in CIMMYT-sponsored training programs has also increased in the past decade. However, it is still less than 10% of the total and is below the share of women agricultural graduates in developing countries. This in part reflects selection criteria used by national programs. We will seek ways to increase the number of women in our training courses.

In making long-term projections of resource allocations, analysis must be leavened with other considerations.

Following the TAC's 1985 recommendation, the CGIAR decided to reduce its investment in wheat by some 10% over five years. By now, the relative investment in wheat has already fallen by a bit more than the recommended amount.

Strategic planning requires explicit statements and assumptions about objectives, about current capabilities, about major dimensions of the future environment, and about criteria for choosing among alternatives, all of which were treated in earlier chapters. Here we turn to their implications for the assignment of our resources among programs, enterprises, and major activities.

In making our planning analytical we were conscious of the danger of also making it "mechanistic." Data limitations, the need to accommodate the unforeseen, and the complexity inherent in applying multidimensional criteria all testified to the need for leavening analytical findings with other considerations. We believe that we have been properly sensitive to these concerns; we raise the point early in the discussion so as to reassure the reader.

As a CGIAR center, we must necessarily be guided by its goals and objectives. These are clearly reflected in the decision criteria treated in Chapter 4. One judgement of the System, not treated earlier, is discussed here because of its importance to priority setting in CIMMYT.

The 1985 TAC Recommendation for Wheat

■ The Technical Advisory Committee of the CGIAR recommended in 1985 that the System's investment in wheat be reduced relative to total investment. The System approved and programmed a reduction in the relative effort devoted to wheat of some 10% over the following five years. The major perceptions shaping TAC's judgement were 1) the high yield plateaus already reached in wheat and 2) the possibility of transferring work to advanced national systems. By 1989, the System's relative investment in wheat had already fallen by more than the recommended amount.

With regard to yield plateaus it should be noted that much of the global investment in wheat research goes toward building new resistances to mutating pathogens with the aim of simply maintaining the plateau. Our investment in wheat also has that characteristic: without it wheat yields inevitably decline because mutations in the pathogens that cause diseases make once resistant varieties susceptible.

Regarding the second perception, recently we have met with representatives of dozens of national programs concerned with wheat in an effort to determine means through which responsibilities might be transferred to national programs. What has emerged as a vehicle acceptable both to advanced and less advanced programs is the concept of "partnership" (see Chapter 6).

Relative to breeding, this mechanism will be systematically attempted and analyzed; it appears promising. Other forms of partnership, we believe, will lead in the nearer term to expansions in international offerings by national programs.

This possibility seems especially likely for in-service training in crop management. As for full transfers of responsibility, some pilot ventures are now being discussed. If implemented successfully—in terms of evenhandedness, timeliness, stability, and cost—then CIMMYT should re-examine its activities with the possibility of widening rounds of transfer. These arrangements, however, cannot lead to significant reductions in the Center's commitments over the next six to eight years.

For various reasons we ask the System to consider reviewing TAC's recommendation and the CGIAR's subsequent decision.

These observations lead us to ask that consideration be given to reviewing the 1985 TAC recommendation and subsequent CGIAR decision. For the future, in light of these observations and with the new opportunities in winter and facultative wheats, we sense that our allocations to wheat are less than adequate.

Allocations Between Maize and Wheat

■ CIMMYT must plan at several levels, applying the same planning logic to each, but perhaps in different ways. Our strategic plan treats the distribution of resources among major programs and support units, between enterprises (research and direct support to national systems), and major activities (germplasm development, crop management research, etc.). *CIMMYT's Five Year Budget: 1990-1994* carries this process on to lower levels of planning, and provides additional insights into the application of our weighted decision criteria. As a point of departure for this discussion, the current distribution of staff across major units is shown in Table 5.1.

In applying our decision criteria, their relative importance rested on a blend of assumption and informed judgement.

Table 5.1. CIMMYT senior and associate staff, by major unit, place of assignment, and funding, 1988.

	Core funds		Extra core		Totals
	Senior	Associate	Senior	Associate	
Maize					43
Base	18	5			23
Outside Mexico	15		5		20
Wheat					42
Base	18	2	2	2	24
Outside Mexico	14		2	2	18
Economics					15
Base	4	1	1		6
Outside Mexico	3		6		9
Support					28
Base	17	9		2	28
Total	89	17	16	6	128

Note: Post docs are not included in this table.

Arbitrary weights were applied to most criteria and then varied to note their impact.

The expected value criterion has two dimensions: the economic value of the crop and the rate of progress anticipated through research.

In applying pertinent decision criteria to the partition between the Center's two major programs, maize and wheat, we attempted to quantify, where possible, their relative importance. This proved feasible, at least in principle, for expected economic value. In other instances, we assigned arbitrary weights to the criteria according to our sense of their relative importance, blending assumption and informed judgement.

Expected value Recall that there are two components to this criterion: 1) a measure of the economic value of the maize, wheat, or triticale being affected, and 2) the anticipated rate at which progress will be achieved. Table 5.2 shows the current maize and wheat production of developing countries valued at 1987 prices (we expect no significant change in the price of maize relative to that of wheat by the year 2000). These measures exclude temperate maize and winter wheat because there will continue to be alternative sources of supply satisfying most needs of national systems for these materials. Even so, later we will argue for a modest commitment to winter and facultative wheats. Note that the economic value of wheat is some 1.5 times the value of maize.

As for the second component, we expect more rapid progress in maize than in wheat over the next five to ten years. Our expectation rests on two observations. The first is that extraordinary progress has occurred in wheat while maize in the tropics and subtropics has moved less rapidly. Because certain key elements and findings are now in place, we believe progress in maize will be more rapid. We acknowledge, however, that weak linkages in the maize sector, especially those related to seed production, must be strengthened if our forecasts about maize are to hold.

Table 5.2. Quantitative indicators of criteria for research resource allocations between maize and wheat (data relate to developing countries).^a

Indicator	Maize	Wheat
Value of current production at current prices (billions US\$) ^b	10.6	16.9
Percentage of total production in countries with incomes less than US\$ 400 per capita ^c	31	67
Percentage used as feed ^d	35	5
Percentage of production from countries with strongest programs	49.7	54.4

a Excludes temperate maize and winter wheat

b Based on FAO, World Bank, and CIMMYT data

c Data from FAO sources

d Based on appraisals from CIMMYT staff.

A second factor suggesting more rapid progress in maize than in wheat relates to estimates of yield plateaus. We believe that the yield plateau of maize will move forward by about 1.5-2.0% per year, while that of wheat will move at less than 1.0% annually. Adding in the losses averted through maintenance research in wheat, we expect gross gains in maize to exceed those in wheat by about 1.5 times. Since farm-level changes tend to follow those in experimental situations, we believe investments in maize research will lead to higher outcomes on the farm than would equal investments in wheat. Finally, to connect the assertions made in preceding paragraphs, on a global basis we see no reason to believe that innovations will diffuse at a different rate in one crop than in the other.

In terms of the expected economic value of a given investment, then, the two dimensions—a measure of economic value and the rates of gain expected in production—balance out, and returns on investments in maize or wheat research would be about the same. Alternatively said, from the standpoint of expected economic value, there is no reason for arguing that one program merits more emphasis than the other.

The poor and food versus feed criteria It appears that more poor people rely on wheat than on maize, a consideration that favors adding resources to wheat. The percentages in Table 5.2 estimate the proportion of relevant maize or wheat grown in countries with less than US\$ 400 of per capita income. For wheat, India, Pakistan, and China dominate on the low side, while for maize, Brazil, Mexico, and Indonesia dominate on the higher side. Given our desire and that of the System to help the poor, this implies that more weight be given to wheat. The food versus feed criterion also favors wheat. It is believed that the proportion relating to wheat for feed in Table 5.2 is too low, but even tripling it still leaves the advantage with wheat. While the weighting schemes used are entirely arbitrary, assigning what seem like reasonable weights to these two criteria suggests that wheat receive on the order of one-third more resources than maize.

Sub-Saharan Africa Attending the System's concern for sub-Saharan Africa, note that on the order of 15 times more maize than wheat is produced in the region, and that virtually all of this maize is destined for food. We believe that the added effort for Africa will entail no less than five years and probably as much as ten years. This suggests more emphasis on maize relative to wheat during that period. Complicating this somewhat is the fact that IITA is an alternative supplier for portions of Africa. This diminishes in some measure the emphasis to our Maize Program, i.e., were IITA not present we would give even more emphasis to maize because of the System's concern for sub-Saharan Africa.

While the economic value of wheat is higher than that of maize, we foresee more rapid progress in maize research. Thus, the two dimensions balance out and returns to investments in either crop will be about the same.

Two criteria—the poor and food versus feed—favor investments in wheat; their relative importance suggests about one-third more resources in wheat than in maize.

Concern for sub-Saharan Africa adds emphasis to maize research by CIMMYT, though less so due to the presence of IITA in the region.

There appear to be stronger alternative sources of supply for wheat—from strong national programs, private sector institutions, and others.

Strong national programs are also more effective in translating our work into gains for farmers.

Alternative sources of supply Temperate maize in developing countries is largely found in China, Argentina, and Chile; developed countries provide a ready source of germplasm and information. This is also true, but to a lesser extent, for winter wheat, which is largely found in China, Turkey, Iran, and Afghanistan. In fact, so substantial are these alternative sources of supply that, to date, we have done little work on either. These considerations led us to give virtually no weight to temperate maize and little weight to winter wheats.

Strong public sector national programs are one alternative source of supply, providing products that can substitute for those of CIMMYT. That possibility suggests giving low weights to CIMMYT products destined for their environments. As well, however, their work can complement our efforts, i.e., strong national programs will take better advantage of our products than will weak programs. This suggests giving higher weights to products destined for strong program environments. This anomaly requires the attention of the System.

Looking just at alternative sources of supply and thinking first of plant breeding, the strongest wheat programs support a somewhat higher portion of total wheat production than do the strongest maize programs. This would suggest relatively fewer CIMMYT resources to wheat than to maize. However, the strongest wheat programs are found in relatively poorer countries while the strongest maize programs tend to be in relatively better off countries. Assuming that the poorer countries support their research programs less well than the relatively better off countries would argue that alternative sources of supply are more likely in maize than in wheat. Yet the historical records of these countries cast doubt on the assumption.

There are few alternative sources of supply for improved wheats in the private sector, nor are any likely unless wheat hybridization comes into its own. For maize, there are many private companies entering the market in developing countries. They tend to concentrate where yield potential is high and where yields are already good. They also rely significantly on CIMMYT germplasm as source materials. We expect that these private companies will expand their efforts in the future, perhaps making them prominent sources of supply toward the end of the century.

On the side of crop management, private chemical companies will offer more fertilizers, herbicides, and insecticides, especially for favored areas. Our view is that maize and wheat will be about equally affected.

On balance, then, our judgement is that stronger alternative sources of supply are more likely for wheat than for maize, suggesting that maize be favored somewhat over wheat. We have not, in this judgement, included the complementarities that stronger programs add to CIMMYT's work. Were we to do so, the balance would tip back in favor of wheat.

The scale criterion Allocation in favor of maize is reinforced when one reflects on the matter of scale. Recall that total returns to increased scale appear to level off rapidly in our work, especially in plant breeding. Current evidence suggests considerably more variation among important maize-growing regions than among important wheat-growing regions. Taken together, these factors imply a need for fewer germplasm improvement specialists in wheat than in maize, even though allocations to wheat carry with them a higher potential total payoff because of the larger production. Consider, for example, that the largest wheat mega-environment accounts for some 40% of all Third World wheat production while the largest maize environment provides only about 10% of total output (many more maize environments account for significantly less than 10% of total output). While, say, 1.5 to 2 professional person years might be allocated to the maize environment, no more than 4 could be assigned to the wheat environment due to the leveling off of returns to scale. The result is more professional resources for maize than for wheat improvement.

In considering the matter of scale, we see a need for more germplasm improvement specialists in maize than in wheat.

Sustaining productivity We see no reason to believe that this criterion should favor one crop more than the other, given that differences between the genetic vulnerability of the crops are addressed through a commitment to aggressive durable disease resistance breeding strategies in wheat (Chapter 6). We will continue our already significant commitment to related themes in training, in germplasm conservation, and in maintenance research. New research in this area will be treated initially on an experimental basis, hence the Center will increase its investment moderately until we have a better sense of the potential for research with new orientations. This is not, we add, because we see the theme as unimportant, but rather because of uncertainty about the potential scope of our role.

The need to sustain the productivity of natural resources affects investments in maize and wheat about equally, as does the need to ensure stable yields.

Stability of yield While acknowledging its importance, we see no reason to argue for one crop over the other on this criterion. Drought is probably the major factor affecting production stability and our preliminary data suggests that roughly the same proportions of maize and wheat are grown under moisture stress.

Minimum critical mass Both the Maize and Wheat Programs currently operate some activities at minimum critical mass levels. In two cases—research on quality protein maize and on triticale—the Center awaits more information about the utility of the products before significantly altering resource allocations. In a third case, that of winter wheat, CIMMYT recently established a small effort to bring the major winter wheat programs of the developing world together. In none of these cases is the Center's current position one of long-run equilibrium. Program leadership will follow these activities carefully and, depending on the course of events over the next half dozen years, these efforts either will be expanded or phased out.

Some of our work is currently done with a minimum critical mass of resources. These efforts will be monitored closely in coming years and will either be expanded or phased out.

To the turn of the century, we see the factors favoring allocations to maize as more significant than those favoring wheat, especially given the System's earlier judgement on wheat. For the longer term, we expect wheat's allocation to rise above that of maize.

Over the next decade, the Economics Program will become somewhat smaller, as planned reductions in OFR-related work more than offset increases in other Program efforts.

A modest increase in resources for information work, computing services, and biometrics is foreseen.

Implications for maize and wheat summarized Briefly, then, the expected returns/expected progress projections balance out, leaving maize and wheat equal. The poor and food versus feed considerations shift the weight toward wheat. The sub-Saharan Africa, alternative sources of supply, and scale criteria, but most importantly the System's 1985 judgement on wheat, bring the immediate balance toward maize. We see the considerations favoring maize as more significant than those favoring wheat, especially given the System's 1985 judgement. For the longer term, with a reduction in weight given to sub-Saharan Africa and with a more favored place for wheat in the System, wheat's allocation would rise above that of maize.

These projections rest on a series of strong assumptions. We will follow these carefully over the period of this plan to assess their continuing validity, making changes in our allocations as the emerging facts suggest.

Allocations to Economics and Support Services

■ Having examined the implications of our analysis for maize and wheat, it is appropriate to talk about our third major program, Economics, and several important research support services. In large measure, of course, changes in support services emerge from changes in the three research programs. That idea is reflected here.

The Economics Program A substantial portion of our current work in economics is now financed through extra-core funding. Much of the work that the Economics Program proposes to conduct is not now being done by others. Moreover, the Program will help the Center sharpen its own research resource allocations. Through the course of the next decade, the Program will be reduced in size, with planned reductions in on-farm research aimed at technology generation and in training associated with that class of research more than offsetting increases in other Program efforts. For on-farm research there are now alternative sources of supply; indeed, we anticipate that national programs themselves should be able to undertake training in this class of work (see Chapter 6).

Information and computing services Increased demand is envisioned for publishing, for scientific information services, and for computing services; hence a modest increase in resources devoted to these activities is anticipated. An increasing demand for biometrics, which is currently housed in systems and computing services, is also anticipated. Some of this demand will occur within the commodity programs; some will emerge from work in biotechnology.

Experiment stations In the past, we have invested heavily in experiment stations. We anticipate that significant investments will be required in the future in order to maintain their high caliber. In addition, we note a strong current demand for training in experiment station management and, while it is

unlikely that this demand will decline by 2000, it is likely that others will offer this service. Indeed, given that experiment station managers must deal with a broad array of crops, it appears that the Center should join the System in looking for ways to expand the offering in this area, perhaps through training programs established around regional centers.

As we now see it, if others expand training in experiment station management, CIMMYT's needs can be met with existing staff numbers but with somewhat larger commitments of funds.

Laboratories What will happen with our laboratories depends on the direction of our disciplinary work, which is expected to expand, and the future structure of the Center. At this juncture, an increase in human resources is a certainty due to an expansion in seed health activities and to added work in biotechnology. As for more disciplinary and more strategic research, those expansions could take place within the maize and wheat programs, or, depending on the class of work and the possibility for complementary efforts, increased efforts could take place through our laboratories.

It should be noted here that we will forge new collaborative agreements with advanced research institutions. In many cases such arrangements will substitute for adding specialized skills to our own staff. At times, of course, there will be greater advantage in developing the needed competencies within the Center. Thus, while direction here is clear, its form is less so.

Allocations Between Enterprises

■ As stated earlier, CIMMYT seeks to strengthen national systems indirectly through research related to maize, wheat, and triticale, and directly through the provision of training, information, and consulting services. These two major classes of work—research and direct support to national systems—are the enterprises of the Center. As shown in Table 5.3 (which is the same as Table 2.1 and is repeated here for the reader's convenience), our resources are currently divided almost equally between these enterprises. A major theme addressed during our planning sessions had to do with whether this allocation would be appropriate as we move toward 2000.

Assuming a roughly constant resource base, we sense that the needs of national systems will be better served should CIMMYT gradually shift resources away from consulting and training and into research. Beyond that, as described in the next section, resources will be reallocated among the activities that make up our major enterprises. Recall that our objective is to open options for the poor and that we achieve that objective by making national systems more effective in meeting the needs of *their* clients, the farmers. However, the effectiveness of national systems is a function of human capital, operating

We project significant investments in experiment stations in order to maintain their high caliber.

Expansions in seed health and biotechnology will require additional resources. The latter will aim at cost-reducing and time-saving applications.

Direct forms of support—training, information, and consulting—help build human capital in national programs. Now, however, other factors less amenable to our influence seem more limiting, including national program budgets, incentives, organization, and infrastructure.

We will give a growing emphasis to the products of research, less to training and consulting. By 2000, well over half our resources will go to research, compared to some 38% today.

budgets, incentives, organization, and infrastructure. We can have a direct influence only on the first variable through training, information, and consulting. Our influence in other realms is less clear.

Representatives of national systems have clearly stated that, for many, the absolute number of trained individuals is not now the key concern. Rather, it is the availability of appropriately trained manpower, i.e., they are seeking a different mix of training opportunities that will help them to meet their changing needs. We are heeding the counsel of our clients and, as is made clear in Chapter 6, are changing the mix of the training opportunities we offer. Beyond those reallocations, we will reduce our investment in training by 2000. The efficient allocation of resources requires that we invest in areas where the expected payoff is relatively high. As we see it, factors other than training now seem more limiting to national programs. We will thus give a growing emphasis to the products of research, less to direct support.

We will be returning to this point near the end of this chapter with some observations that better follow discussion of allocations among major activities (see *Direct Support to National Systems, Revisited*, this chapter). For now, note that in 2000 the Center expects to be investing well over 50% of its resources in research activities overall (compared to the current 38%). Much of this in-

Table 5.3. Percentages of senior and associate staff time allocated to different activities, by place of assignment, 1988.

Activity	Headquarters	Regional and bilateral programs	Total
Germplasm improvement	21.9	7.3	29.2
Crop management research	3.6	2.4	7.0
Social science research ^a	1.8	1.0	2.8
Total research	27.3	10.7	38.0
Training	9.7	10.2	19.9
Information ^b	4.5	2.8	7.3
Consulting	2.8	8.0	10.8
Total direct support	17.0	21.0	38.0
Administration	13.9	4.0	17.9
Other	5.3	0.8	6.1
Total administration/other	19.2	4.8	24.0

a Done by the Economics Program staff, much of the work in economics is included in crop management research.

b Contributions of Information Services staff were allocated 50% to direct support to national programs, 25% to administration, and 25% to headquarters research.

Note: Post-docs are not included in this table

crease, but not all, will come at the expense of certain forms of direct support to national systems. Significant reallocations will occur within this enterprise, along with a reduction of from about 40% to some 25% of the Center's resources.

Allocations Among Major Activities

■ We have identified six major sets of activities through which we seek to serve the poor of developing countries. The reader is directed to the companion publication, *Toward the 21st Century: Strategic Issues and the Operational Strategies of CIMMYT*, for a full treatment of our operational strategies and their underlying rationale. Strategies relating to each activity are briefly noted below in the context of resource allocations. Table 5.3 portrays the percentage of our total effort currently directed to each activity. Table 5.4 shows how allocations will change to 2000.

Germplasm improvement The development of improved maize, wheat, and triticale germplasm is our major activity and one in which the Center has a unique advantage, something of a natural monopoly. This advantage emerges from our role as the hub of germplasm networks that facilitate sharing of plant materials while improving them. By centralizing the activity, rather than

Developing improved germplasm will remain our major activity.

Table 5.4. Projected percentage allocations of senior and associate staff time among different activities, by place of assignment, to 2000.^a

Activity	Headquarters		Regional and bilateral programs		Total	
Germplasm improvement	28	(21.9)	8	(7.3)	36	(29.2)
Crop management research	4	(3.6)	7	(2.4)	11	(7.0)
Social science research ^b	4	(1.8)	2	(1.0)	6	(2.8)
Total research	36	(27.3)	17	(10.7)	53	(38.0)
Training	6	(9.7)	5	(10.2)	11	(19.9)
Information	5	(4.5)	4	(2.8)	9	(7.3)
Consulting	3	(2.8)	3	(8.0)	6	(10.8)
Total direct support	14	(17.0)	12	(21.0)	26	(38.0)
Administration	13	(13.9)	4	(4.0)	17	(17.9)
Other	3	(5.3)	1	(0.8)	4	(6.1)
Total administration/other	16	(19.2)	5	(4.8)	21	(24.0)
Grand total	66	(63.5)	34	(36.5)	100	(100.0)

a Current allocations are presented in parentheses.

b As stated in the text, the size of the Economics Program will decline; the amount of social science research, however, will increase significantly as allocations to on-farm research and related training decrease.

partitioning into several hubs, each focused on a particular environment, we more fully exploit complementarities and spillovers. The Center will continue to feature germplasm improvement through the remainder of the century.

We will maintain our maize germplasm conservation activities, and more attention will be given to conservation of wheat germplasm. This work will be done in closer cooperation with others.

In organizing its improvement work, CIMMYT will be concerned for yield potential to an extent commensurate with each of the environments for which it works, for yield stability, for conventional norms with respect to nutrition, and for the various qualities required by important markets. Traits for accommodating major biotic and abiotic stresses will be combined in reasonable ways. For stresses of lesser importance, special trait materials will be provided to those for whom the problem is relatively important. In addition, as cropping systems intensify we will give added consideration to maturity classes.

Activities in maize germplasm conservation will be maintained, while activities relating to wheat will undergo some change. Under a recent agreement with ICARDA, developed in consultation with IBPGR, ICARDA will be responsible for maintaining a base collection for durum wheat and the wild relatives of wheat. At the suggestion of donors and clients, CIMMYT is now negotiating with IBPGR for an expanded role for its base collections. Each center's base collection will be duplicated at the other for safety. Once the new base collections have been established, active collections will be formed for evaluation and seed distribution. With respect to both maize and wheat, more effort will be made to foster the development of networks of gene banks in developing countries.

Our germplasm improvement efforts conform well to CGIAR guidelines; they are international in scope and we have a clear cost advantage. An increasing portion of our resources will go to this activity.

Seed health work will be expanded, initially in wheat with maize following, given evidence of need. This expansion largely applies to physical facilities, to support staff, and to collaborative work.

Earlier discussion has spoken of the changing strength of national programs, of our increased emphasis on mega-environments, on germplasm development, and on our commitment to the idea of research partnerships. These considerations will lead to more research through our regional programs and more research through partnerships, especially in wheat.

Our work on germplasm improvement conforms well with System concerns, i.e., it is international agricultural research in which CIMMYT has a clear cost advantage. We expect to devote an increasing portion of our core funds to this activity (Table 5.4).

Crop management research There is little doubt that crop management will be the principal source of productivity increases in farmers' fields over the next dozen years. More research resources must be used more effectively to ensure that farmers enjoy widespread access to efficient technologies.

Beyond that, adding pressure to the demand for crop management research is the concern for sustaining productivity. Much of this work must be approached through crop or, even better, system management.

Through the years, crop management research has been featured in the Center's training programs, and we have worked with national program colleagues as they pursued their ends. To date, however, except for experiment station work in support of plant breeding, we have been little involved in direct research on the management of maize and wheat, except through work done with national programs where our staff cooperate in the pursuit of national program goals.

Our work in crop management research features collaboration. While we envision a continuation of this approach, future directions rest on several perceptions: that national programs will invest more in this area; that portions of the training in this work can be done in conjunction with national programs; that other centers with regional mandates—IITA on maize in West and Central Africa and ICARDA on wheat for drier areas—will play an increasing role in such work; that much of the needed work is location specific, hence not easily congruent with CG guidelines; and, finally, that while broad-based work in sustaining productivity might have large payoffs, a period of experimentation is required in order to assess the extent to which results can be generalized.

To support selected national programs' efforts to meet the burgeoning demand for location-specific crop management work, we will turn to special project funding. The Center will ensure that such work recognizes the importance of sustaining the productivity of the resources committed to agriculture. We will be concerned with research that has potential application outside the country on which it is focused and with countries exhibiting firm support for agriculture and its research.

Later reference will be made to our interest in diagnostic tools for crop management research. Many argue that this is a major shortcoming in such work. Our bilateral work will also support our broader efforts on diagnostic tools.

Given these views, the following developments are projected. With core funds, we will continue crop management research in direct support of plant breeding. Also with core funds, a clearinghouse function will be established to promote the systematic sharing of results from work (ours and others) aimed at country-level problems, at issues related to sustaining productivity, and at work in support of plant breeding. With core and special project funds, we will initiate two or three projects aimed at long run productivity questions. If the results turn out to be widely applicable—for example, across the rice-wheat rotations of the Asian Subcontinent—we will augment this class of work. Core and special project funds will also be used to develop diagnostic techniques. With extra-

Most agree that improved crop management will be the principal means of increasing farm-level productivity to the turn of the century, and that major opportunities await national systems.

Our approach to CMR features collaboration, and future directions rest on several assumptions and perceptions.

New initiatives in CMR include an information clearinghouse function, several projects aimed at long-run resource productivity questions, the development of diagnostic techniques, and CMR projects with selected national programs. We will allocate less to regional agronomy programs.

core funds we will undertake crop management research with selected national systems.

If anticipated extra-core support is available, especially for research aimed at sustaining productivity and for bilateral projects, then crop management research will increase relative to germplasm improvement. In all cases, CIMMYT staff will participate more fully in the research dimensions of the activity.

The Economics Program will shift its efforts “upstream,” away from adaptive OFR and toward applied/strategic research.

Economic analysis of research priorities and impacts Analyses of research priorities and impacts will form a growing part of our future research portfolio. This work will be led by the Economics Program. The results will be of direct use to CIMMYT and, beyond that, will serve well the needs of national programs. These changes represent a considerable shift in emphasis away from the adaptive and toward applied/strategic work. They will increase core support to economic analyses and reduce overall support, especially in training and networking, to on-farm work in technology generation.

Training In reviewing our training activities, several conclusions were drawn: that generalized training in germplasm improvement should be continued; that the bulk of the Center’s generalized training in crop management should be shifted to national programs, to country-focused efforts, or, especially in the case of sub-Saharan Africa, to joint programs involving several centers; that we should offer more specialized training in all phases of our work; and that the Center should refocus its visiting scientist program, taking fewer people for longer periods and with more precisely defined objectives.

CIMMYT’s current investment in training is higher than the CGIAR average. We will reduce our allocations to this area and will change the mix of our offerings to more closely match the needs of national programs.

Notice in Table 5.3 our considerable investment in training, higher than the average for the System. Based on the discussion here, a reallocation accompanied by a reduction of work in training can be expected. More energy will be devoted to the preparation of training materials, to supporting the initial efforts of national programs to establish their own training programs, to specialized courses, and to the support of visiting scientists. Efforts in generalized training on crop management (production agronomy) will diminish as will widespread training efforts currently undertaken through extra-core funding. These represent significant changes in our portfolio of work. The judgement rests heavily on the assumption that national programs will fill the gap and, indeed, will expand the range of alternatives available. We must monitor developments carefully; if our expectations are not realized, we must rethink our strategy.

Some of the reduction in direct crop management training will be offset by more collaborative crop management research in selected countries, leading to the sort of indirect enhancement that accompanies working together with others, each coming to know more. As more collaborative research in crop management occurs, this kind of human capital development will increase.

Information There are three comments relative to information. First, the distribution of information will be increased to all national programs. Gains in the efficiency of information dissemination make this possible at ever lower costs. Second, much of what we have described above—the preparation of training materials and the synthesis and further dissemination of research results from country programs—will require additional professional skills dedicated to these tasks. Finally, as noted earlier we anticipate an increase in our efforts in both computing services and biometrics.

Distribution of information to national programs will increase, as will our emphasis on training materials. Computing services and biometrics will also expand.

Consulting In accordance with the forecast of stronger national systems, we will reduce our commitment to consulting. Representatives of national systems have expressed a desire for more structured efforts, and we are convinced that economies can be achieved by doing so. The distribution of nurseries will, of course, continue but the international testing of germplasm will take on new dimensions. To the extent that CIMMYT monitoring of that testing is required, it will be done in large measure from the base in Mexico or from other convenient locations housing Center staff. For areas not easily served through these sources, we will consider other options.

Consultation with national programs will be reduced and our efforts will become more structured.

Conclusion This concludes the discussion of the six major activities through which we deliver our various products and services. For each activity we have referred to what is expected to occur with respect to the commitment of human resources. Table 5.4 summarizes the kind of changes that we expect to see over the next decade or so. The human resource assignments in that table rest on the assumption that CIMMYT in 2000 will have approximately the same number of staff as it does today. It should also be noted that these assignments apply to our broad enterprises. Casting these conclusions in terms of more specific activities, e.g., assignments to maize germplasm improvement for each of the high altitude mega-environments, is a task for our five-year budget. And it should be noted that work on the detail of the five year budget might well turn up opportunities that will cause us to modify the allocations presented here.

Direct Support to National Systems, Revisited

■ Earlier we commented on our perception that national research systems, in particular publicly funded national programs, are less frequently constrained by human capital and more by operating budgets, incentives, organization, and infrastructure. Even so they are, on balance, generally growing stronger. We have also commented on our intention to increase our activities with selected national programs. It might be asked if these judgements are congruent.

Developing country investments in agricultural research are decreasing in real terms.

While we are optimistic about national systems, we are also conscious that developing country investment in agricultural research is no longer growing, indeed it is decreasing in real terms. This might well be only the influence of the current economic malaise and the historically unprecedented external debt.

We believe that new examples of the efficacy of CMR will improve the prospects for added investments.

Economic activity will increase again, and debts as a portion of national output will decline. But will agricultural research again encounter the support of a decade ago, and will it grow beyond that to even more appropriate levels? We have no straightforward answers to those questions, but we have no doubt that new examples of the efficacy of research will improve the prospects for support.

Taking the argument another step, we believe that crop management research is relatively underfunded in developing countries. At the same time we believe that it offers greater promise for the near term than do other lines of work.

On both counts, we perceive challenges for CIMMYT and see work focused on a few countries as the most expeditious way forward. In the best situation, we would join with other centers and with national program researchers in concerted research on major issues, whether in biology, research management, or in policy. Research priorities would be set in terms of country priorities, obviously, but as well emphasis would be given to questions of sustaining productivity and to topics in biology with applications beyond the country.

We will move toward a few collaborative research projects, each serving several countries but with work concentrated in one. We will document the returns to these efforts and seek to demonstrate to others the payoff of such investments.

Especially in the case of crop management research, we believe that the "few-country" approach is more promising than a regional approach. This is particularly true where a major aim is to rekindle an interest in agricultural research through convincing demonstrations of its potential.

These are the arguments that support our interest in working with selected programs. This might be on a bilateral basis or through a hybrid combining aspects of bilateral and regional programs.

As for germplasm improvement, this better suits regionally organized efforts. Even here, though, we expect to see these activities involve more research than in the past.

So, we believe national systems will continue to gain strength. That process will be enhanced, however, if interest in agricultural research is high and that in turn will be more likely if convincing new demonstrations of returns to research are at hand. We believe CIMMYT has a role in this process.

All of this suggests a reduction in the Center's core-supported regional activities. We believe, however, that this should be offset by an increase in extra-core activities related to crop management research and to long term research on productivity. Each line of work, of course, will require a broad mix of professional skills from CIMMYT, we would hope from other centers, and from national systems.

Resource Allocations Summarized

The major conclusions from the discussion relate to the relative investments in maize and wheat, in research and direct support to national systems, and in each of our six major activities. These, in turn, rest on a few critical assumptions about the future.

Between Maize and Wheat

The plan calls for a greater allocation to maize than to wheat over the planning period, largely because of the System's 1985 judgement about wheat, and because of scale considerations and CGIAR concern for sub-Saharan Africa. Should these considerations be put in doubt then wheat allocations could exceed those to maize. In this context we would favor a TAC review of the 1985 judgement regarding the relative, System-wide investment in wheat.

Between Enterprises

Among our major enterprises, there is a shift in emphasis toward research. The relative decline occurs in consulting and training. One implication of this shift is that core-funded regional activities will decline. At the same time, an expected increase in bilateral support for crop management research will bring the total investment in our activities outside Mexico to roughly current levels.

Among Activities

A shift toward crop management research is anticipated relative to other research activities. Even so, we have scheduled a greater absolute increase in germplasm improvement. The major underlying assumptions are, first, that larger gains are attainable in the next dozen years through crop management research than through germplasm development or through economic research. The next is that national systems will continue to strengthen, implying an opportunity to substitute national systems for CIMMYT in the supply of some products. Finally, we assume that the

major opportunities in crop management are best treated by national systems.

Our assumption about the national systems has an especially strong impact on our commitments to training and consulting, and through them for the allocation between enterprises and among activities. Total allocations to training will decline most notably in production agronomy. As well, there will be internal shifts towards training for mid-career professionals and developing training materials. Allocations to information will increase slightly.

Two additional comments, each obvious, are appropriate. First, the changes described in this plan will not occur overnight, but will be well under way within five years. And second, we must follow closely our crucial assumptions to ensure their relationship to unfolding events; if any diverge in notable ways, we must readress our strategies.

CIMMYT's planning began with the identification of strategic issues confronting the Center. Subsequent discussions centered on major operational strategies for dealing with those issues. Here we highlight key strategies and, by implication, the strategic issues considered. A separate document, rich in technical detail and underlying rationale, has been published under the title *Toward the 21st Century: Strategic Issues and the Operational Strategies of CIMMYT*. Those interested in a more comprehensive discussion are directed to that publication.

Germplasm Improvement

We will increase slightly our emphasis on lowland tropical maize, and do more to improve source and special-trait populations. We will increase the products available for hybrid development, and produce fewer experimental varieties.

■ We identified seven strategic issues relevant to germplasm improvement. Significant tactical concerns, not presented here, were also treated during planning.

Germplasm product mix As the needs of our clients change, so will our array of products and the relative emphasis we give to each. While little change in relative demand is expected for the Maize Program's primary products, demand for hybrids in many client countries is expected to grow. Private sector seed companies will meet much of the increased demand for seed, especially in the more favored production areas; public sector institutions will contribute relatively more to research than to seed production. The relative share of demand for bread wheats and durum wheats will remain stable; triticale's share of the market may increase.

The Maize Program will slightly increase its emphasis on lowland tropical products relative to that given to subtropical materials, primarily as a response to the growing interest of private companies in subtropical maize. We will support such public/private sector complementarities in germplasm improvement to an extent consistent with our desire to strengthen national systems.

We will continue to provide advanced wheat lines while increasing the distribution of segregating populations. Special-trait populations may also be formed.

CIMMYT supplies segregating populations, intermediate germplasm products, and parental materials to national programs. They, in turn, may release them directly as final products or make further refinements. Both uses of the Center's materials will remain important, though their use as intermediate steps to final products will likely become more common as national programs improve their breeding capacities. In response to increased demand for source materials, the Maize Program will place more emphasis on improvement of agronomically acceptable source populations and special-trait populations that can serve as donor stocks. The Program will produce fewer experimental varieties ready for release and will increase its various products for use in hybrid development (early generation inbreds, source materials, and parents for non-conventional hybrids). Greater need for early generation wheat germplasm products will lead to increased distribution of segregating populations. Where demand is sufficient, some special-trait populations may also be formed. The

Wheat Program will continue to provide advanced wheat lines (F_6 and F_7), in high demand as parental stocks by advanced national programs and as potential releases by other programs.

Quality considerations in both maize and wheat appear to be of growing strategic interest. Research on quality protein maize will continue into the 1990s at its present level, at which time our investment in this research will be reviewed. Improved bread making quality will be a more important breeding objective by 2000 and new screening techniques hold promise for increasing the efficiency of selection for quality traits.

Broad versus specific adaptation Broadly adapted germplasm gives high, stable yields over time and across diverse production environments. Germplasm adapted to specific conditions, on the other hand, produces significantly higher, more stable yields in particular environments. Our concern for improved efficiency leads us to a strategy of developing germplasm that is broadly adapted within mega-environments (see box, *Mega-environments: Our Conceptual Framework for Allocating Resources*). Germplasm targeted for one mega-environment may have much in common with that developed for another, and a significant proportion of CIMMYT's germplasm will therefore be tested for its potential in more than one mega-environment. We will rely on national programs to select for adaptation specific to their needs.

Genetic variability CIMMYT will exploit a wide range of sources for enhancing the genetic variability of its crops, placing greatest emphasis on the approaches that are least costly and most consistent with the Center's germplasm improvement objectives. Within-species genetic variability will by no means be exhausted by the turn of the century, and it is important that we assemble, conserve, and evaluate existing variability for important traits.

However, the Center's crops appear to have limited variation for some traits: wheat for tolerance to extremes of heat and drought and maize for tolerance to extreme drought, very low fertility, and severe insect attack. We anticipate that almost all of the variability required to sustain genetic gains until 2000 will come from intraspecific sources. The remainder will come from interspecific sources (through crossing with near relatives by means of wide-cross techniques) and intergeneric sources requiring gene transfers. Although they will be small in number, interspecific and intergeneric transfers are expected to play a particularly important role in wheat breeding.

The transfer of single genes from one genus to another—transgenesis—holds considerable promise for genetic improvement of characters controlled by a limited number of genes. It also poses several problems, among them relatively high costs and potentially complicated legal circumstances. Because of the high cost of transgenesis techniques and products, CIMMYT will not

QPM work will be continued into the 1990s and then be reviewed. Improved bread making quality will become a more important wheat breeding objective.

We will develop germplasm that is broadly adapted within mega-environments.

We will assemble, conserve, and evaluate intraspecific sources of genetic variability. We will also explore inter-specific and intergeneric sources, applying new scientific techniques developed by others.

undertake to develop them. Rather, the Center will view itself as a consumer and conduit of them. We will also provide training and consultation to national programs in the adaptation of new techniques to their germplasm improvement efforts. (Biotechnology is more fully discussed in Chapter 3.)

Our global responsibility for conserving and evaluating maize landraces will continue.

Germplasm conservation CIMMYT's role in germplasm conservation rests on its commitment to sustaining the productivity of agricultural resources in developing countries. We will continue to accept our global responsibility for conservation and evaluation of maize landraces. In evaluation we will concentrate on specific traits for which there is insufficient genetic variability in advanced germplasm. To improve the efficiency of evaluation, curators will establish a core collection representative of all of the major genetic complexes thought to exist in each species. This collection will be available upon request to national programs.

Mega-environments: Our Conceptual Framework for Allocating Resources

Mega-environments are broad, not necessarily contiguous areas, usually international and frequently transcontinental, defined by similar biotic and abiotic stresses, cropping system requirements, consumer preferences, and, for convenience, by a volume of production of the relevant crop sufficient to justify the attention of an international breeding program. Germplasm products generated for a given mega-environment are useful throughout it, accommodating major stresses but perhaps not all of the significant secondary stresses.

By way of example, one of the more important mega-environments for maize improvement is characterized as requiring tropical lowland, late-maturing, white dent germplasm with resistance to *H. maydis*, *P. polysora*, and to fusarium ear and stalk rot; this mega-environment produces an estimated 6.8 million tons of maize on some 3.8 million hectares distributed across 18 countries.

Using the same considerations we also define macro- and micro-environments. The former are smaller and more uniform areas, all of which are included in one or another mega-environment.

They are important enough to warrant investment by a national program, and perhaps by a regional organization. Micro-environments are localized areas for which a high degree of specific adaptation is desirable. In this case, narrowly focused investment is usually not warranted and farmers must rely on materials that meet only some of their needs.

In a similar manner, there are mega- and macro-environments for crop management research. Here, common agronomic problems provide common research themes. For example, the millions of hectares of land occupied by rice-wheat rotations, distributed across five countries in Asia, appears to constitute an agronomic mega-environment. Within this area are macro-environments related to land preparation practices, planting dates, etc. Environments defined for crop management will rarely be congruent with those defined for crop improvement and are generally smaller and more numerous, reflecting the greater location specificity of crop management practices. Our research will provide principles which then serve national programs as starting points for developing recommendations for farmers.

Under a recent agreement with ICARDA, developed in consultation with IBPGR, CIMMYT will maintain a base collection for bread wheat and for triticale. ICARDA will be responsible for maintaining a base collection for durum wheat and the wild relatives of wheat. Each base collection will be duplicated at the other center for safety. Once the new base collections have been established, active collections will be formed for evaluation and seed distribution. We will strongly support initiatives for establishing regional wheat and maize germplasm banks as additional backups.

Maintaining genetic gains "Maintenance" research is aimed at defending genetic gains by developing resistances to constantly evolving pathogens. Because of ephemeral disease resistance in many self-pollinated crops, varieties have to be replaced with relative frequency. Hence, this issue is of greater concern to the Wheat Program, which currently invests some 50% of its breeding research resources in maintaining and expanding effective disease resistance.

We are committed to improving the durability of biotic stress resistance in wheat over the next two decades and will seek to increase the efficiency of the Program's work in this area. In both wheat and maize, general resistance to obligate parasites will receive special attention so as to increase the durability of our germplasm products. Another option, whose purpose is to prolong the utility of less durable resistance genes, is to use varietal mixtures and multilines. We believe this approach has considerable potential for selected national programs.

Marginal environments CIMMYT defines marginal wheat environments as those characterized by various abiotic stresses, including frequent drought, high temperatures, acidic high-aluminum soils, salinity and phosphorus, and nitrogen and micronutrient deficiencies (see box, *Marginal Lands and CIMMYT's Research Agenda*, Chapter 4). In maize, the effects of these constraints may be exacerbated by insect attack.

In addressing marginal environments, we recognize that crop improvement will often not be the best option. Where the necessary technology and inputs are available, crop management has considerably greater potential than plant breeding for alleviating the effects of environmental stress. However, for resource-poor farmers in marginal areas where inputs and technology are lacking, genetic improvement for stress tolerance may be the only viable option even though genetic gains in productivity and yield stability will come slowly and at considerable cost.

Having identified the major environmental stresses and assessed their global importance and distribution, we are now developing appropriate germplasm. The tasks that lie ahead are to refine and deploy more reliable and rapid screening methods and techniques for managing stress factors so as to

CIMMYT will maintain a base collection of bread wheat and triticale; ICARDA will do the same for durum wheat and wild relatives.

General resistance to obligate parasites will receive special attention in a concerted effort to improve the durability of our germplasm products.

Our strategy for marginal areas reflects the resource-poor farmer's need for genetic materials with greater stress tolerance.

enhance the expression of genetic variability in our germplasm. We will continue to evaluate the utility of the many testing sites we use for screening germplasm and, as a part of that process, we anticipate an expansion of partnership agreements with national programs (see below) who have access to unique, high quality selection sites. We will also seek to employ better screening techniques and we will apply new statistical techniques in experimental design and analysis.

We are exploring possibilities for decentralizing our breeding efforts still further. For the next decade, however, we will favor the partnership form of involving national programs.

Decentralization Our experience with decentralization makes us amenable to further exploring the idea. Generally, it has proven effective to move portions of our breeding programs to environments not represented in Mexico. The Maize Program has strengthened its breeding work by decentralizing to various locations where specific diseases or abiotic stresses occur. The Wheat Program has enjoyed considerable success with shuttle breeding, in which several sites are used in sequence to incorporate stress tolerances specific to the sites.

Neither of these decentralization options have involved the actual transfer of functions to national programs. In our view, the transfer of full responsibilities to national programs over the next two decades warrants careful examination. If costs can be reduced while increasing support to selected national programs and maintaining the confidence of those receiving the service, then the strategy represents a potentially important improvement in satisfying developing country needs. In some cases, such as for some classes of training, we believe that this can be achieved. In other cases, such as germplasm improvement, we are less certain. We are organizing fully representative pilot projects, and will follow them carefully. Success in these will lead to more such transfers.

For the next decade, however, we will favor the partnership form of involving national programs. Under such an arrangement, CIMMYT and selected national programs contractually agree to jointly plan and execute on behalf of all of the Center's clients some aspect of the Center's program that is of mutual interest. Partnerships, several of which are already underway, will be built around sites that typify important mega-environments, particularly those whose environmental stresses are not adequately represented in Mexico.

Crop Management Research

Our CMR efforts must have international extensions.

■ Though CIMMYT is best known for its germplasm, we view crop management research (CMR) as important in opening options to the poor and as a complement to germplasm improvement. Much CMR is location specific, adaptive in nature, and hence better done by national programs. Our CMR work must have international extensions. This encourages our concentration on strategic research for which the Center has a special advantage, as well as on increasing the efficiency with which CMR is conducted.

As we see it, CIMMYT has potential advantage in CMR related to sustaining productivity, primarily because such research requires longer time periods than many national programs can accept. Further, the work we propose will have application across broad areas in several countries, implying that we can count benefits more broadly than will national programs. We also see a role as an integrator and distributor of agronomic information, and see the development of diagnostic tools and methodologies as activities that offer a high rate of return and for which CIMMYT is particularly well-suited. Finally, some CMR is needed in support of plant breeding.

CMR on the issue of sustaining productivity is envisioned, as are several other CMR activities for which CIMMYT is well suited.

Sustaining productivity This is a potentially important area of work. As we see it, our role will be that of drawing together researchers from concerned national programs; facilitating priority setting, choice of techniques, and the division of work; and providing linkages with donors.

Marginal environments We remain committed to research aimed at alleviating production constraints, increasing the efficiency of input use, and stabilizing production in maize- and wheat-based systems in marginal environments. In selecting target locations for research, we will favor areas of high return, such as those where only a single factor, like soil acidity, prevents the environment from being high yielding. We see our role more as one of adapting existing technology for stress management rather than one of developing new techniques. ICARDA, for example, allocates relatively more of its resources to CMR in marginal wheat environments than does CIMMYT, and we anticipate significant spillovers to other regions from their work in the West Asia-North Africa region.

Our CMR in marginal areas will favor those of potentially best returns, such as where a single factor inhibits productivity.

On-farm research Much of this work will be done in conjunction with multidisciplinary work emphasizing a single country but in environments shared by several countries. As well the Economics Program will pursue such work as part of its efforts to develop procedures for allocating research resources and for policy analysis.

Economic Analysis of Research Priorities and Impacts

■ CIMMYT's Economics Program provides analyses and information to research managers, both in the Center and in national programs. We also work on appropriate analytical methods and procedures to improve national program priority setting.

In analyzing research resource allocations, we will complement the domestic resource cost methods currently used with several additional techniques.

Analysis of research resource allocations Current work in this area employs domestic resource cost methods, which are especially appropriate where price policy distortions hide the underlying comparative advantage of a crop or of a production technology in a region or country. In the future, a somewhat broader range of techniques will be employed, including more formal crop loss assessments, refinements to scoring methods to include considera-

tion of spillover effects from one environment to another, and, for some specific problems, ex-ante benefit-cost analyses and demand studies (such as on the future demand for maize as a food and feed grain).

We will initiate a socioeconomic database that will enable us to assess the distributional consequences of new technologies.

Impacts of maize and wheat research on the poor The continuous nature of our planning process requires attention to assessing the impacts of research. As a start, we will initiate a comprehensive database on socioeconomic indicators, maize and wheat production, consumption, and prices, utilization of improved germplasm, and use of inputs in maize and wheat production. This database will enable us to assess the distributional consequences of new maize and wheat technologies, and will be strengthened over the next few years to allow rapid analysis of tradeoffs posed by CIMMYT planning.

We will augment our current global and regional assessments of maize and wheat economies with well-focused country level studies.

Commodity sector and policy analysis Maize and wheat research decision makers, both in national programs and in CIMMYT, need to understand longer term trends in the maize and wheat economies at the global, regional, and national level. We already have a modest but successful research effort in this area, with results published in our *World Wheat Facts and Trends* and *World Maize Facts and Trends* series. We will continue this series. Well-focused maize and wheat commodity sector and policy studies at the country level will also be undertaken, which should prove useful to national systems as they set their research priorities. A product of these studies will likely be methods for commodity sector analysis and for utilizing such information in setting research priorities or analyzing policy alternatives.

The consequences of the trend toward privatization of research will also be examined.

The effects of privatization We will initiate a modest research effort to assess the consequences for CIMMYT and national programs of the trend toward privatization of research. Alternative institutional arrangements for exploiting the complementarity of private and public sector research will be evaluated, and we will determine the value of patented products to the Center and to national systems in relation to their cost. Since these issues are common to other international research centers, we will seek opportunities for collaboration.

Training

We will transform our training in fundamental ways.

■ One of CIMMYT's major activities in direct support of national programs is training, and most staff spend some portion of their time engaged in training-related activities. In response to the expressed needs of national programs, we will transform our training in two fundamental ways: 1) we will increase the array of specialized and advanced training opportunities, and 2) we will support national programs as they assume more responsibility for in-service, entry-level training in CMR.

Specialized in-service training The Center will offer more specialized courses for mid-career researchers. Possible themes include priority setting and management in crop breeding, specific methodological issues and topics in crop management, and social science methods for on-farm research and agricultural research policy.

We will offer additional specialized courses...

General in-service training We expect that more advanced national programs will assume responsibility for entry-level training in CMR for their own staff as well as for others. Hence, we will decrease our investment in this area over time and eventually phase it out. Entry-level training at headquarters will continue in crop improvement (breeding, pathology, entomology, physiology). We will continue with training in experiment station management, and support the development of intercenter coordinated training courses in this area, expecting to play an active role in fostering such intercenter cooperation.

...shift entry level CMR training to advanced national programs while continuing our offerings in crop improvement and experiment station management...

Advanced training More opportunities will be provided for visiting scientists from developing countries. The program will give more emphasis to those who can profitably work on well-defined research projects relevant both to their institutions and to our own work. Under the program, up to six research fellows will be invited annually to spend three to six months in Mexico. We will increase positions for post-doctorals and are developing new ways to cooperate with developed country universities on specialized training for developing country graduate students.

...and increase the array for advanced training.

Building national program training capacity We will increase our efforts to assist national programs with in-service training courses, especially in CMR. Central elements of the task will be training materials, systems for sharing information with other institutions offering similar types of training, and organization of in-service courses, especially in CMR. Should national training capacity not progress as hoped, and should there be no other alternative suppliers for such general training, we will re-evaluate our potential contributions.

We will offer assistance of various kinds to national programs undertaking in-service training, especially in CMR.

Information

■ Information work occurs at all levels within CIMMYT and will become increasingly important, both to the Center and its clients. In the CIMMYT context, information is both a product and a collection of services. The latter—communications, the scientific information unit (SIU), and systems and computing services (SCS)—are provided in support of research. Two sets of clients shape our work—those internal to the Center (scientific staff, management, the Board of Trustees) and those external (national programs, disciplinary colleagues, and donors).

Information work will become increasingly important to CIMMYT and its clients.

We will produce more technical reports and practical manuals, and give more emphasis to publishing in refereed journals.

Using new technologies, we will increase the accessibility of scientific information, first to Center staff and then to national programs.

Strategic information will be managed according to uniform standards and practices.

We will shift our consulting efforts to more focused and structured forms of interaction.

Product mix in publishing We will give added emphasis to publishing information of a more technical nature, some of this in support of our greater emphasis on research, and to developing practical guidebooks and manuals to enhance the research and training capabilities of others. While a high proportion of this additional reporting will be under the CIMMYT imprimatur, management will encourage staff to publish key findings in refereed journals.

Accessibility to scientific information With research information expanding rapidly and costs to developing countries rising notably, there is need for a range of information services. Through new technologies, we will increase the accessibility of scientific information, first to the Center's own staff and then to colleagues in national programs, using traditional library collections and through various new services and systems. These "clearinghouse" products and services may include maize, wheat, and triticale abstract and bibliographic journals, retrospective bibliographic database searches, current awareness services, controlled document delivery services, selected CD-ROM products, and, once optical disk technologies are adequately developed, we will evaluate the costs and potential utility associated with "grey" literature databases.

Information management systems We will establish uniform corporate standards and practices for the management of strategic data and information. Responsibility for data management will be placed as close as is practicable to end users, and the Center will bolster end-user support services.

Consulting Services

■ Consulting takes a variety of forms, including joint field visits to inspect breeding materials, direct participation in national program activities, informal demonstrations of procedures, techniques, or equipment, sponsorship and participation in various workshops, monitoring tours, participation in the formulation of research plans with national programs, and consultation on interactions between research programs and national policy makers.

National programs now ask that we shift to more focused and structured forms of interaction. We will comply with that request and, as the effectiveness of our consulting improves, we will reduce the resources we commit to such services.

Previous chapters have focused on various aspects of the planning process, as well as on relevant outcomes. This chapter deals with the implications of our plan for the Center's structure and organization, staffing, culture, and physical facilities. The implications for funding and for relations with national systems are also treated. In the context of the discussion, we review certain long-standing arguments concerning our *modus operandi*, especially that pertaining to the role of disciplinary research.

Structure and Organization

■ It is said that "form should follow function," i.e., we decide first what we should do, then how we should organize to do it. The resulting internal structure should contribute to our long-term operational efficiency. The Center's current structure has resulted from decisions taken about the products and services we deliver and, as well, to which clients. It therefore follows that, as the Center's offerings change over time, it may prove desirable, indeed, necessary to modify our structure.

As CIMMYT's offerings change over time, it may prove necessary to modify our structure.

Current structure Chapter 2 describes our current structure. The Maize, Wheat, and Economics Programs account for the bulk of the Center's products and services. While this will remain true, we envision some increase in the relative importance of products in which our information and our data processing services play prominent roles.

Having two breeding programs makes good sense because specialized knowledge about each crop is more advantageous than is specialization within plant breeding, per se.

The primary rationale supporting our current structure, setting the Economics Program aside for the moment, is that our principal products are improved maize and wheat germplasm. Then why, it might be asked, not have a single germplasm improvement unit responsible for both commodities? The answer lies in the biology and logistics relating to the two crops. While both are cereals, they are sufficiently different—one is self pollinated and one is open pollinated, they tend to be grown in distinctly different physical environments, and breeding takes place in different locations during the same crop cycle—that there are clear advantages in treating them separately. Two breeding programs make good sense because specialized knowledge about each crop is more advantageous than is specialization within the area of plant breeding.

As for the Economics Program, similarities between maize and wheat in fixing research priorities, in farm level production considerations, and in markets for inputs and product are such that specialization in the economics of one commodity versus the other offers little advantage. A single program permits sufficient staff for specialization within the discipline of economics. Here, the advantages of disciplinary specialization exceed the advantages of specialized knowledge about the economics of each crop.

For economics research, the advantages of a disciplinary program outweigh specialization in our two commodities.

Potential for additional disciplinary specialization Over the years, CIMMYT has considered at various times the merits of organizing around disciplines rather than around commodities. We have chosen to operate within

A disciplinary organizational form favors, among other things, scientific outputs; a commodity form favors the production of improved germplasm. We seek to capture the benefits of the former while maintaining the latter

The differences between maize and wheat are great to cytogeneticists, physiologists, and entomologists, suggesting advantage in commodity specialization.

Regarding pathology, the diseases affecting small grains are far more important than those affecting maize, leading us to favor commodity specialization.

The case of agronomy is less clear.

the commodity construct. Now we seek to capture some of the primary benefits of the former, while preserving the advantages of the latter.

Favoring a disciplinary organization are the notions that staff are more likely to stay abreast of current developments within their specialties, that standards for evaluating work can be more exactly tailored, that scientific output, *per se*, is likely to be increased, and that techniques used in work relating to one crop are more easily transferred to another. On the face of it, greater specialization is particularly appealing in the cases of cytogenetics/wide crosses, physiology, entomology, pathology, and agronomy/crop management.

On the other hand, a commodity approach—one that combines several relevant disciplines into a commodity oriented team—is more likely to lead to output in the form of improved germplasm than is a disciplinary organizational form. A commodity approach also favors some aspects of agronomy/crop management research (discussed more fully below).

To 2000, we will continue to give more emphasis to producing improved germplasm than to scientific output related to germplasm. However, we do see the latter growing in relative terms. Rapid growth in science will offer new efficiencies in germplasm improvement, but only if we stay abreast of developments in various disciplines. Obviously, what we need is a structure that facilitates the delivery of our principal products, but one that also raises the probability of keeping us abreast of new developments in relevant disciplines.

What, then, is the potential for additional disciplinary specialization? First of all, as in plant breeding, the differences between maize and wheat to cytogeneticists, physiologists, and entomologists are so great that we remain convinced an organizational advantage lies with commodity specialization over those disciplinary specializations. Moreover, the Center employs few such individuals currently and their numbers are not likely to increase substantially by 2000. Regarding pathologists, most of the demand is for small grain pathology and we have a sufficient number to permit specialization among diseases. In terms of facilitating the delivery of our principal products, we argue that the commodity/disease specialization better contributes to our efforts than would an alternative format.

In the case of agronomy the argument is less clear. We see advantage in some limited specialization on each crop so as to ensure experiment station conditions appropriate for plant breeding. Much of our current agronomy portfolio, however, is invested in strengthening national systems. Surely, the specialist in maize agronomy will have more knowledge about maize to offer national system agronomists than would a specialist in cereals, but the extra value for most of their work is not easily discerned.

On the other hand, maize and wheat tend to be grown in different geographic areas in the developing world. Given the importance of knowledge about conditions in specific regions and that there is little overlap between the two crops, there seems to be little advantage on this count in forming a single program in agronomy. Even if such a program were formed, specialization in maize or in wheat would tend to occur.

Even if an agronomy program were formed, specialization in maize or wheat would tend to occur.

There are, nonetheless, potential advantages related to management, *per se*. The Maize and Wheat Programs are large operations. Until recently, they were not organized in a hierarchical fashion, i.e., nearly all staff reported to the Program directors. A separate agronomy program offers a way to increase the management input. As well, a separate agronomy program would imply added status for the function, which could be a positive force in promoting needed investment in agronomy within national systems.

A separate agronomy program would, however, offer advantages in management.

At this point it should be noted that our approach to agronomy/crop management research advocates a clear understanding of both the underlying biological and economic considerations that shape farm-level decision making. Most of our work in this area is done in conjunction with national systems and aimed at enhancing their capabilities in such research. We have invested heavily in developing and diffusing research procedures for farm-level work. These procedures apply to both maize and wheat and, indeed, with varying degrees of fit, to many other crops.

To the extent that common practices and tools are important, then, it can be asked why we do not form a "Production Program," including in it those agronomists and economists involved in enhancing the capacities of national systems in production agronomy. There is merit in the idea.

While there is merit in the idea of forming a "Production Program," several considerations argue against it.

At least three considerations, and perhaps a fourth, argue against it. The first is that we expect to reduce our commitment to this class of work by our regional programs because we believe that alternative suppliers are at hand. A second is that, to the extent we continue with such work beyond, say, five years, we expect to do so through bilateral undertakings: in those instances, the management function will be delegated to each project. Third, research on productivity issues appears to involve sufficient crop-related subtleties that specialization by crop will be advantageous. And a fourth consideration, one over which the Center has only marginal influence: if the CGIAR continues with its current emphasis in this arena—for example, in sub-Saharan Africa—then one might ask whether there should be System-wide collaboration in such work, perhaps based on agroclimatic regions, and with a new management structure.

The potential for specialization, revisited So, having argued that plant breeding, cytogenetics/wide crosses, physiology, pathology, and agronomy/crop management should remain within a commodity-based structure,

In pathology and agronomy/crop management, we see advantages to forming functional, across-program disciplinary groups, each led by a principal scientist who will facilitate group activities.

each thereby contributing more effectively to delivering germplasm, how do we acquire some of the advantages accruing to a structure based on disciplines?

We believe that a significant portion of these advantages can be attained through the organization of functional across program groups for pathology and agronomy/crop management. Our cytogeneticists will soon be sharing common facilities, which will help to reinforce professional bonds. In physiology and entomology the numbers are so small that little advantage in functional groups is evident. In pathology and agronomy/crop management, however, the numbers are large and advantages to some disciplinary grouping are commensurate.

To this end we will appoint a principal for each group whose primary function will be to organize group activities aimed at reporting on the orientation of current work, the presentation of results, and bringing new findings to the fore, as well as at encouraging the development of papers and ensuring peer review. Principals will be guaranteed adequate time to perform these tasks and evaluation of their contributions to the Center will include their performance in this role.

We believe that such a structure will provide access to emerging science, with its incorporation into the work of CIMMYT and that of national systems, while maintaining our efficiency in the production of our primary outputs. Principals will coordinate their efforts with the Deputy Director General of Research.

Structure of regional and bilateral activities Over the past 15 years, our commitment to activities outside Mexico has increased notably; today, some 40 staff are working in regional or bilateral programs around the world. While our work outside Mexico has increased, we have maintained essentially the same management structure that prevailed when we initiated our first regional effort. It is appropriate that we now reexamine that structure.

Envisioned changes in the mix of off-campus activities call for a new management structure.

With the exception of assessing and reporting back to base on the performance of germplasm, off-campus activities are largely in direct support of national programs. Off-campus staff consult with national program colleagues and conduct training on germplasm improvement and crop management research, especially on-farm research. In addition, some staff are actively engaged in germplasm improvement, *per se*, such as those located in Zimbabwe and Thailand. We envision a change in the mix of off-campus activities, reducing those that constitute direct support (e.g., training and consulting) in favor of augmenting off-campus research (in germplasm improvement, long run productivity issues, and crop management). Accompanying this, we project a modest overall decline in core-funded regional activities and an increase in special project-funded activities (see *Implications for Funding*, this chapter).

As part of our recent External Management Review, an independent management professional examined the Center's activities outside Mexico. After consideration of the consultant's report, we revised our format for the management of regional and bilateral programs. An array of functions and responsibilities for regional liaison staff were identified, and we designated the individuals in each region who will fulfill these duties. We also modified and formalized the reporting relationships between regional programs and headquarters.

We have identified an array of functions and responsibilities for regional liaison staff, and we have modified the reporting process between regional programs and headquarters.

With respect to administrative matters, liaison staff constitute the primary channel through which regional staff report to headquarters. On matters pertaining to science, the Maize and Wheat Programs have designated subprogram coordinators at base to whom regional staff report directly, depending on the issue at hand. Economics Program regional staff report either to the Program director or his associate, depending on the region.

Overall research coordination As we framed our plan, we gave attention to overall coordination of research. Subsequent discussions with the External Program and Management Review panels and with our Board of Trustees helped us to shape a new structure having two important features. A Management Advisory Committee made up of the Director General, his two deputies, and the three program directors has been formed. This committee advises the Director General on matters relating to policy and operation of the Center.

A management advisory committee has been formed that advises the Director General on policy and operational matters.

As well, we redefined the deputy directorate relating to research, expanding the position by having the three programs report there rather than to the Director General. Important among the duties of the position, the Deputy Director of Research will guide and coordinate the three research programs and related research support units, especially to ensure the operation of appropriate mechanisms for priority setting, resource allocations, monitoring, and evaluation.

The DDG/Research will guide and coordinate CIMMYT's research programs and related support units.

We believe that these two changes will enhance our management capability. At the same time they will enable us to continue capitalizing on the major advantages of our strong program leadership.

The process through which we set priorities and allocate resources for our major enterprises was discussed in Chapter 5. Here we expand somewhat on points made there relating to priority setting and allocations of resources within the two commodity programs.

In setting priorities within the research programs, we apply the same criteria used in setting overall priorities.

Essentially, the process used to allocate resources within the Wheat Program to bread wheat, durum wheat, and triticale, and within the Maize Program to lowland tropical, subtropical, and highland maize, and then in each case to special classes of material, involves the application of the same criteria

used in setting overall priorities. The basic framework for assessing importance is the mega-environment (see box, *Mega-environments: Our Conceptual Framework for Allocating Resources*, Chapter 6).

While we have established a more transparent decision process, implementation will benefit from refinement.

Some of the criteria used in Chapter 5 figure more prominently in setting priorities within commodity programs than at the Center-wide level. In particular the stability and minimum critical mass criteria come into play. Also of more importance at this level is the researcher's view of the potential for progress and the rate at which it can be achieved. This level of priority setting and resource allocation is reflected in our five-year budget.

While we believe we have established a process that makes more transparent the relationships among our goals, priorities, and resource allocations, we also believe implementation will benefit from further refinement. It will be especially important to refine the data describing the poor within each mega-environment, to relate changes in technology with changes in income flows and to overall development, and to assess the returns to research in crop management and sustaining productivity. These themes are on our research agenda for the near future.

Implications for Staffing

Changes in our emphasis among activities will lead to changes in the mix of professional staff in CIMMYT. We foresee fewer economists, more CMR specialists, more plant breeders, and more staff in molecular biology, biometrics, and information.

■ The shifts and changes discussed earlier will have implications for the mix of CIMMYT's staff and for the ways in which we approach staff development. These points are briefly reviewed below.

Disciplinary mix Through the course of the presentation there have been specific references to the Center's disciplinary mix. In the context of only limited growth (see the final section of this chapter for a discussion of CIMMYT's future size) we envision: 1) a decline in the number of economists, largely because of a projected decline in our participation in training in on-farm research; 2) an increase in crop management professionals, given an expansion in bilateral activities; 3) an increase in plant breeding staff; and 4) increases in staff associated with molecular biology, biometrics, and information.

Our major changes will occur less in the disciplinary mix and more in what the mix signifies, i.e., we see professional categories themselves taking on different characteristics through the next decade or so. These changes will occur through staff development programs and through staff turnover. This point is discussed below under the section *Implications for CIMMYT's Culture*.

Headquarters and off-campus staff A comparison of Table 5.3 with Table 5.4 in Chapter 5 reflects the change anticipated in the proportion of our staff assigned to headquarters. It is evident that changes are anticipated in the mix of activities. As for the off-campus staff we are projecting a decline in the amount of time devoted to general training and consulting, and an increase in

that devoted to research. While the professionals involved might well carry the same labels in the future as they do today, their skills and expertise will be different, e.g., with less emphasis on the skills associated with training and consulting and more on those associated with research.

Off-campus staff will spend less time in training and consulting, more in research.

Staff development strategies Staff development must be a major concern over the next decade. Earlier we described the growing strength of national systems and the expansion in scientific knowledge. Each consideration implies that staff must constantly invest in their own professional development, so as to stay abreast of their disciplines and thereby ensure access to the potential through new science. As we see it, the expansion in scientific knowledge will occur across the board, implying that virtually all of our research professionals must be sensitized to new developments and their potential applications. Only in this way can we expect to stay current and be effective in serving our clients

Staff development is a major concern and we will encourage the use of our study leave program.

The Center and its staff must invest significantly in human resource development. One institutional vehicle for achieving this, a study leave program, was put in place in 1987, and in time we expect a strong demand by staff for access to its benefits.

Implications for CIMMYT's Culture

■ During the next decade, our organizational culture will no doubt evolve. Some changes will occur simply because new staff bring with them new ideas and orientations that challenge existing norms and values. Other changes will be brought about by design, through modifications in the Center's management strategies and structure. Care will be taken, however, to avoid significant modifications in those attributes that are the positive hallmarks of the Center's culture.

Our organizational culture will continue to evolve, due to staff turnover and to changes in management strategies and structure.

New staff, new orientations CIMMYT has enjoyed a stable staffing pattern over the past 20 years, with turnover averaging around only 5% annually, and most of that occurring among staff with less than five years in the Center. This stability has contributed to our capacity to address problems within the context of longer term horizons. It has also resulted in a slowly advancing institutional age profile, with the majority of staff now in the 40-50 year age group. Beyond the need to ensure effective staff development opportunities, this fact is not, in and of itself, cause for concern. It does, however, accent the importance of the staff development effort.

New staff add new dimensions to thinking, and often use a different set of tools to achieve the same ends as their predecessors.

While veteran staff remain among the most innovative, new staff add new dimensions to thinking. As an example, the plant breeders of today, while bearing the same title as plant breeders who obtained their credentials 30 or 40 years ago, generally start their careers using a different set of tools to achieve the same ends as their predecessors. New scientific staff spend relatively more

Management will encourage staff to maintain closer professional relationships with colleagues on the "cutting edge" of science. The need to stay abreast will grow, and that means more time reviewing the literature and more time contributing to it.

time using computers, for example, and more time documenting their efforts. In our work, the emphasis remains on a pragmatic approach, with long hours being the norm, but those hours are gradually being allocated differently. This sort of change is evolutionary in nature, and results from the progress of science: management need do little to encourage it, save perhaps to ensure that it is not unduly hindered.

Cultural change by design Certain aspects of our organizational culture may not prove suitable to the CIMMYT of tomorrow. While some of these aspects would likely be affected over time by the kind of evolutionary change noted above, there are positive steps that management can take to expedite needed change. For example, a greater investment of staff time into developing and maintaining closer professional relationships will be encouraged. Clearly, the informal means of communication with our peers that has served us so well in the past will continue to be important, but staff will need to increasingly engage in the kinds of activities that ensure their being up to date on the science of their professions. This means staying in closer contact with those on the "cutting edge" and giving more attention to professional activities. The "disciplinary principals" mentioned earlier will help, but all staff will find it increasingly necessary to enhance their professional contacts. Operationally that means (among other things) more time reviewing the literature and more time contributing to it. Only in that way can we remain sufficiently abreast of changes in science to turn them to our advantage and to the advantage of our clients in developing countries.

Staff will also be expected to spend more time sharing information with one another.

A second important change that management will encourage has to do with internal communication, i.e., between scientists, especially in different programs, and between scientific staff and those who serve in support programs. Fostering improved internal communication requires resources, primarily the time and energy of an already busy staff, but we believe that poor communication has high attendant costs and that those costs will increase in the future. We also believe that those costs outweigh the resources needed to redress them; hence, management will encourage staff to spend a greater portion of their time sharing information with one another. A range of formal and informal means to this end will be employed, from the disciplinary groups described earlier, to formal seminars, to "brown bag" lunch discussions.

And staff will be encouraged to more closely attend to the needs of their families.

Third, management will strive to make it possible for staff to devote more attention to the needs of their families, so that the Center remains a wholesome place to work. To the extent possible, we will seek to ensure opportunities for spouses; at a minimum, bureaucratic impediments to such opportunities will be reviewed, with an eye toward eliminating them.

Avoiding undesirable change There are a number of attributes of our culture that should not change, that endure by virtue of their positive influence on the Center and its clients. As noted in Chapter 2, these attributes include a

primary focus on the effectiveness of national systems, our evenhandedness in dealing with clients, an emphasis on direct involvement by scientists in all or most phases of research, a belief in pragmatism based on the needs of farmers, an open association with a worldwide network of practitioners sharing the same principles, and our nonpolitical nature. These attributes seem as appropriate for the future as they were in the past. If combined with continued stability in funding and (in certain respects) staffing, they provide us with the freedom we need to continue taking a longer term view of research and its potential contributions to helping the poor. Management will strive to maintain these attributes, reflecting them in the Center's policies and its operational strategies for the future.

Management will strive to maintain the positive attributes of CIMMYT's culture, reflecting them in policies and operational strategies.

Implications for Physical Facilities

■ There appear to be a number of significant implications for the Center's physical facilities associated with our resource allocations and strategies for the future.

Experiment stations In large measure, the effectiveness of breeding research aimed at developing improved genetic materials is contingent upon the quality of the experimental sites used. We have invested heavily in experiment station facilities (primarily in Mexico, but elsewhere as well) to ensure that progress is both "real" and expeditious. As the Center's relative commitment to research increases in the future, close attention will be given to monitoring the utility of the stations we use today; the need for such monitoring is reinforced by our belief that the Center has a special advantage in offering training in experiment station management. Some disturbing trends already affecting the stations we use have been identified. These trends vary in importance from station to station, as do their potential consequences. This variability aside, significant investments in experiment stations will be required as we move toward 2000.

We will monitor the utility of the experiment stations we use, and foresee investing in this area during the next decade.

Laboratories As we strengthen our research, notable investments in laboratory facilities will be required. Several of our current facilities, which were entirely suitable for our goals and objectives of the 1970s and 1980s, will need to be upgraded. In addition to probable changes in the orientation of some of our lab work (changes implied by modifications in some of our research objectives), desirable new techniques and equipment are becoming available. The specifics of such investments are tactical considerations and hence will be discussed more fully in our five-year budget.

Our new molecular biology lab will soon become operational, and we will upgrade other lab facilities as new techniques and equipment become available.

One major implication should be discussed here, that of our investment in a molecular biology lab. As stated in Chapter 3, current breeding techniques will remain the most important methods of crop improvement and genetic manipulation to 2000. Biotechnology will contribute to these forms of research, however, especially in the areas of selection efficiency and genetic variability available to breeders. Our strategy calls for close monitoring of developments in biotechnology and research aimed at testing and adapting specific tools for use in our

circumstances and, eventually, the circumstances of national programs in developing countries. To implement this strategy, we are now building and staffing a new molecular biology laboratory. The facility will be staffed by first one and later two molecular biologists (senior staff), five to six postdoctoral fellows and visiting scientists, and the required number of technicians. The objective of the new unit, which will operate across programs, is to contribute to the effectiveness of the Center's germplasm improvement research.

Additional investments may be required in computing services, electronic equipment maintenance, and seed storage facilities.

Other plant and equipment In addition to the allocations described above, certain other significant investments may become necessary. In particular, we must remain open to the possibility of investing additional resources in systems and computing services as new generations of hardware and software are proven. Also, as we make increasing use of ever more sophisticated electronic equipment of all kinds, we will need to consider adding support staff to maintain it. Finally, our expanding commitments in the area of germplasm conservation imply additions to our seed storage capacity.

Implications for Funding

Ours is a fiscally conservative plan. We do not envision major expansions in staff and facilities.

■ In any discussion of the future, prudence requires that a plan for funding accompany the plan of action. That theme and some of the issues relating to CIMMYT's size are the topics of this section.

Financing the plan Ours is a fiscally conservative plan in that we do not envision major expansions in the number of our staff nor, except for the expansion in laboratories where funds are already in hand, do we contemplate major expansions in our physical facilities. We do see the need for some changes in the locations of our experiment stations, and any relocation will require access to additional funding, as will the anticipated additions to our germplasm storage facilities.

Projected growth in CMR will require bilateral funding.

We have also alluded to our expectation that the projected expansion in crop management research will occur through bilateral funding. We shall seek to plan these projects with already interested donors. Through that strategy we expect that projects and funding will be consistent.

Having said that our plan is fiscally conservative, it can be argued that the CGIAR will be under heavy financial pressure during the next decade. Some argue that the entrance of new centers will stretch the System's funding capacities. Some claim that the dollar, the CG's unit of account, will increase in value against other currencies making it that much more difficult to gain the required dollars from non-dollar denominated contributions. Aware of these arguments and cognizant of their implications, we have commissioned a study aimed at assessing alternative sources of funding for the Center.

CIMMYT's size After growing rapidly during the past decade, it is interesting to speculate on future growth. We can easily argue that the payoff from

such added activities will exceed that through other forms of investment open to donors. We confess to the belief that the potential through CIMMYT is high, even to the belief that it might well be higher than through many other undertakings. We believe that we could effectively manage a larger staff. Even so, we think that through the course of the next five years or so advantage lies in realizing the reallocations described in the plan, with only modest expansion. Major expansions should await new information.

For the next five years, we will focus our energies more on reallocating existing resources along the lines described in our plan.

Along with others we are now working on ways to decentralize some activities, transferring them to selected national programs. To now these discussions have concentrated on work in wheat, particularly in relation to increasing the national system commitments to training. Beyond that, however, the discussions on decentralization also relate to wheat breeding.

What will happen on this front is still not clear. In particular, no concerted effort has yet been made to assess the reactions of those countries who would rely on the countries selected to provide inputs now coming from CIMMYT. In due course we shall have a sense of those reactions.

We are working with selected national programs on ways to decentralize some activities. Even if these efforts are successful, we foresee no reductions in staff. Resource savings would shift toward upstream research.

As we envision the process, any movement to decentralize breeding should include a period of partnership during which we cooperate closely in sharing a defined responsibility. Through the course of several years, responsibility would shift from our shoulders to those of selected national systems. During the course of the partnerships, we could establish the relative costs of the decentralized systems, not only their direct costs but as well the indirect increases in our costs due to lesser economies of scale and lesser benefits from spillover effects.

With appropriate marks on the important counts—quality, reliability, evenhandedness, and costs—decentralization could continue. Now, two further comments. During these partnerships, we see no reduction in our own need for staff. Later, with decentralization a fact, we would expect to transfer resulting resource savings to more strategic and basic research.

Our clients will have more access to research support and less to direct support; the tools of new science will be more readily available to them; we will offer to assist in developing their training capacities; and we will offer more CIMMYT training for mid-career staff.

Implications for National Systems

■ Without trying to be complete, it is useful to list some of the major implications of this plan for our national system clients. First, we will give greater emphasis to strengthening national systems through research and less to their direct support. The expected results will be easier access by our clients to the tools of new science and a growing stream of research results on high priority themes. We expect to see our clients develop their own capacities for certain classes of training or to rely on neighbors for some of the training currently being done by us. CIMMYT will provide stronger training programs for midcareer professionals. While other implications emerge from the plan, we see these as the major effects for national systems.

Monitoring involves tracking changes in the major elements affecting planning, while evaluation involves judging the quality of our efforts and our rate of progress.

Management combines these efforts, also ensuring that our priorities are right and that they are being followed.

A standing committee on strategic planning will monitor key elements, ensuring that new information and assessments can influence our strategies.

CIMMYT will ensure an "ever green" strategic plan to meet the changing needs of our clients and to facilitate management of the Center to 2000 and beyond. Doing so will require the abiding attention of top management and the periodic participation of other key staff. Monitoring and evaluation will be coordinated from the Office of the Director General, with participation at many levels within the Center characterizing the process.

We think in terms of a multifaceted approach to monitoring and evaluation. We see monitoring as the process through which we keep track of changes in the significant elements of our operating environment, of the continuing relevance of our goals and their importance with respect to one another, of our resource flows, and of the extent of our impact. It is essentially an accounting function. For resource flows, we use budgets and other sources of information to determine whether resource allocations accord with the priorities established in the strategic plan and five year budget.

Evaluation, on the other hand, is the process by which we judge the quality of our efforts, the rate at which progress is being made, and whether the impacts we are having are the desired ones. Evaluation implies having objectives against which to measure progress.

Monitoring and evaluation come together as management seeks to ensure that our priorities are right, that resources are allocated according to those priorities, that the payoffs associated with actual allocations are sufficient given alternative investment opportunities, and that progress toward defined goals is satisfactory.

Monitoring

■ We are doing a number of things relative to monitoring. To stay current with changes in our operating environment, we have established a standing committee on strategic planning that will monitor the key elements described in Chapter 3 and that will conduct studies as needed on topics of special relevance to the effective management of the Center. This regular and close scrutiny of environmental factors affecting CIMMYT, especially the strength of national systems and changes in science, is central to our vision of strategic planning as a process that assures potential for timely change in response to changing circumstances. A key objective is to avoid the inertia often observed in maturing organizations. For example, new decision criteria may well surface, those already in use may change in terms of their relative importance, or national programs may exceed current expectations as alternative sources of supply. We seek to ensure that new information and assessments are available to shape our strategies and performance goals. That is the mandate of the standing committee on strategic planning, which will report on a regular basis to the Director General and to the Management Advisory Committee.

Other activities are considered part of the monitoring function as well. For example, we consider our increased emphasis on publishing to be a viable way of ensuring increased contact with peers and tracking changes in science. And to enable careful consideration of actual resource allocations relative to those intended, we will enhance our management information systems, i.e., we will do

more to quantify actual allocations and, through state-of-the-art computer systems and databases, to track activities. In this regard we are establishing a greater level of specificity in our accounting process to permit a more accurate tracking of resource flows.

Administrative infrastructure is being added.

Evaluation

■ We are strengthening the management function generally by more clearly defining staff performance objectives, ensuring that those objectives are congruent with overall priorities, and measuring progress toward them. We will obtain professional counsel in this respect, and once management has decided upon refinements in the Center's evaluation system, training in its implementation will be provided to managers at all levels.

Performance objectives are being more clearly defined and are being used in evaluating staff.

Beyond staff evaluation, we will be relying more heavily on selected Board members to serve in explicit program evaluation capacities. Our Board of Trustees comprises a uniquely relevant reservoir of talent and experience upon which the Center can rely in its evaluation efforts. In this respect, selected Board members can serve as independent consultants in the evaluation of specific Program-level projects. They will focus not only on the science of the projects, but on their relevance to overall Program objectives and to the Center's strategic goals. Board members serving in such a capacity will report to the Management Advisory Committee and the Director General, as well as to the Board itself.

Selected Board members will help evaluate specific Program-level projects.

In addition, we will utilize "blue ribbon panels" whose members would serve for some time to conduct periodic state-of-the-art reviews of our activities. Their findings would be provided to the Director General and to the Management Advisory Committee.

"Blue ribbon panels" will periodically review various activities.

As yet another measure of the quality of the work being done by the Center, management will track the publication trend. Publishing will become an explicit reference point in establishing staff performance objectives and in staff evaluations, with more weight in some cases, less in others. Management is fully cognizant that good applied science can be done with less emphasis on publishing. What we seek is appropriate balance between conducting useful research and publishing its results.

Publishing will become an explicit reference point in staff evaluations.

Finally, evaluation needs to be done relative to our mission. To what extent are our activities contributing to improving the welfare of the poor in developing countries, and to increasing the productivity of resources devoted to maize and wheat? The Economics Program has begun devoting explicit attention to analyzing impacts relative to the allocation of resources. These analyses will be used by the Management Advisory Committee and the Director General to shape future research priorities and resource allocations.

Evaluation relative to our mission will be facilitated by the Economics Program's analyses of impacts in relation to resource allocations.

Our monitoring and evaluation efforts will aim at ensuring that CIMMYT adds to its formidable contributions to the poor of developing countries. We are confident we can do so.

Bibliography

- Byerlee, D. Maintaining the momentum in post-Green Revolution agriculture: A micro-level perspective from Asia. International Development Paper No. 10. East Lansing: Michigan State University, 1987.
- Brown, L.R., et al., eds. *State of the World, 1987: A Worldwatch Institute Report on Progress Toward a Sustainable Society*. New York: W.W. Norton & Company, 1987.
- CGIAR. Summary of *International Agricultural Research Centers: A Study of Achievements and Potential*. Based on study of the same name directed by Jock R. Anderson. Washington, D.C.: The World Bank CGIAR Secretariat, 1985.
- CIMMYT. *1987-88 CIMMYT World Wheat Facts and Trends. The Wheat Revolution Revisited: Recent Trends and Future Challenges*. Mexico, D.F.: 1989.
- _____. *1986 CIMMYT World Maize Facts and Trends: The Economics of Commercial Maize Seed Production in Developing Countries*. Mexico, D.F.: 1987.
- _____. 2000 and Beyond: NARS' Perspective on CIMMYT's Future Agenda. A Proceedings of the Conference held September 12-14, 1987. Mexico, D.F.: 1987
- Cohen, J.I., ed. *Strengthening Collaboration in Biotechnology: International Agricultural Research and the Private Sector*. Proceedings of a Conference held April 17-21, 1988 in Rosslyn, VA. Washington, D.C.: Agency for International Development, Bureau for Science and Technology, 1989.
- Dalrymple, D.G. *Development and Spread of High-Yielding Wheat Varieties in Developing Countries*. Washington, D.C.: Agency for International Development, Bureau for Science and Technology, 1986.
- Dalrymple, D.G. *Development and Spread of Improved Maize Varieties and Hybrids in Developing Countries*. Washington, D.C.: Agency for International Development, Bureau for Science and Technology, 1988.
- Egan, G. *The pragmatics of excellence: getting business into the organization*. Chicago: Loyola University of Chicago, 1987.
- FAO. *Agriculture Toward 2000*. Rome: 1984.
- Hanna, N. *Strategic Planning and Management: A Review of Recent Experience*. World Bank Staff Working Papers, Number 751. Washington, D.C.: The World Bank, 1985.
- Longmire, J.L. *Longer term developments in the world cereal's markets: Looking towards 2000*. Draft paper, Economics Program. Mexico, D.F.: CIMMYT, 1987.
- Marchand, D.A., and F.W. Horton, Jr. *Infotrends: Profiting from Your Information Resources*. New York: John Wiley & Sons, Inc., 1986.
- Mellor, J. *The new global context for agricultural research: implications for policy*. IFPRI Food Policy Statement No. 6. Washington, D.C.: IFPRI, 1986.
- Mosher, A.T. *Some critical requirements for productive agricultural research*. The Hague, Netherlands: ISNAR, 1982.
- Pfeiffer, J.W., L.D. Goodstein, and T.M. Nolan. *Understanding applied strategic planning: A manager's guide*. San Diego: University Associates, Inc., 1985.
- Sarma, J.S. *Cereal Feed Use in the Third World: Past Trends and Projections to 2000*. IFPRI Research Report 57. Washington, D.C.: IFPRI, 1986.
- Scandizzo, P.L. *Agricultural Growth and Factor Productivity in Developing Countries*. Economic and Social Development Paper No. 42. Rome: FAO, 1984.
- Technical Advisory Committee (TAC) to the CGIAR. *Report of the second quinquennial review of the International Maize and Wheat Improvement Center (CIMMYT)*. Rome: FAO, TAC Secretariat, 1982.
- _____. *CGIAR Priorities and Future Strategies*. Rome: FAO, TAC Secretariat, 1987.