

**Renewal of the CGIAR:
Sustainable Agriculture for Food Security
in Developing Countries**

**A Vision for the CGIAR:
Sustainable Agriculture for a Food Secure World**

Table of Contents

A VISION FOR INTERNATIONAL AGRICULTURAL RESEARCH 41

FOREWORD 41

ACKNOWLEDGMENTS 42

THE CHALLENGE 43

FOOD PRODUCTION PROSPECTS 46

TWO SCENARIOS 50

THE WAY AHEAD 51

INTERNATIONAL PUBLIC RESEARCH 56

A FUTURE FOR THE CGIAR 59

CONCLUSIONS 63

BOXES

 The Challenge of Globalization 46

 Global Pollution Caused by Agriculture 48

 Using Natural Enemies to Kill Pests 53

 Farmer Participation in Agricultural Research and Development 56

 Participants in Potential Partnerships in International Agricultural Research 60

FIGURES

 Figure 1. Population by Regions, 1990 and 2025 65

 Figure 2a. Crop Yields in Asia 1961 to 1991: Composite of Maize, Rice, and Wheat 66

 Figure 2b. Crop Yields in Africa 1961 to 1991: Composite of Maize, Rice, and Wheat 66

 Figure 3. World Grain Production per Person, 1950 to 1993 67

 Figure 4. Suggested Programs and Their Features 68

BIBLIOGRAPHY 69

APPENDIX I: ABOUT THE PANEL 70

APPENDIX II: TECHNICAL ANNEX ON PROJECTION METHODOLOGY 72

TABLES

 Table 1. Country/Region and Commodity Coverage in the IFPRI Model 74

 Table 2. Key Exogenous Parameters in the IFPRI Model 75

 Table 3. Projected Food Gaps in 2025 for Different Assumptions about Hidden Needs 76

A Vision for CGIAR: Sustainable Agriculture for a Food Secure World

A VISION FOR INTERNATIONAL AGRICULTURAL RESEARCH

*A Statement by an External Panel
Appointed by the Oversight Com-
mittee of the CGIAR*

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The work of the Panel was supported by a grant from the Swedish Agency for Research Cooperation with Developing Countries (SAREC). The statement reflects the opinion of only the panel and not necessarily of the Oversight Committee, which commissioned the effort, or of the parent organizations of the panel members.

July 1994

FOREWORD

The challenge the CGIAR has been facing in 1993 and 1994 was the contrast between an extended mandate and stagnating or decreasing financial support from its donors. In this situation the need for a vision that is shared by its stakeholders and broadly understood was evident. Such a vision should be accessible to policymakers and scientists alike. It also should guide the adjustment process in the CGIAR. At its regular meeting in Washington, D.C. in October 1993, the Group, therefore, decided to commission an expert panel to prepare a future vision of international agricultural research with a view to making a convincing case for increased support to the CGIAR.

What was needed was a vision that was imaginative, forward-looking and reflective, covering the next 20 to 30 years. To ascertain that it be fresh and unencumbered by internal CGIAR interests, it was felt that it should be written by scientists without close personal affiliation to the CGIAR.

Recruitment of the expert panel and organization of its work was done by the CGIAR Oversight Committee. Professor Gordon Conway, Vice-Chancellor of the University of Sussex, UK, chaired the panel. Other panel members were Dr. Uma Lele, University of Florida, USA; Dr. W. James Peacock, Commonwealth Scientific and Industrial Research Organization, Canberra, Australia; and Dr. Martin Piñeiro, an independent consultant living in Buenos Aires, Argentina. Dr. Peter

Hazell of IFPRI, Washington D.C., USA and Mr. Michel Griffon, CIRAD, Paris, France assisted the panel as resource persons, and Dr. Selçuk Özgediz of the CGIAR Secretariat as working secretary. Henri Carsalade and Johan Holrnberg from the CGIAR Oversight Committee participated throughout in the work of the panel.

The panel held two workshops. Panel members interacted with TAC and with the Oversight Committee. A final draft was compiled and presented by Professor Conway to the meeting of the CGIAR in New Delhi in late May 1994. Final editing of the draft was done first by Professor Conway and later, in July, by Henri Carsalade and Johan Holmberg to reflect the discussion in New Delhi as well as other comments on the draft.

Preparation of this report was, thus, very much a collective effort, and my sincere appreciation goes to all the individuals mentioned above who participated in the exercise. However, Professor Conway's untiring efforts were instrumental in bringing the process to a successful conclusion under a very tight time schedule. It is, thus, first and foremost to him that the CGIAR owes much gratitude for this report.

Vision, adjustments in governance and financing, and the interphase with national programs are key components

for a reinvigorated CGIAR. This vision statement is a contribution to this goal. SAREC's support in financially supporting the work of the panel and in publishing this report is gratefully acknowledged.

Paul A. Egger
Chairman
CGIAR Oversight Committee

ACKNOWLEDGMENTS

The members of the panel gratefully acknowledge the helpful comments and criticisms they have received from many individuals, in particular from members of the CGIAR's Technical Advisory Committee, from staff and directors of the CGIAR's international agricultural research centers, from staff of a number of independent institutes, in particular the Institute of Development Studies at the University of Sussex, the International Institute for Environment and Development in London, and from staff of the panel members' own institutions, the Centre for International Cooperation in Development-Oriented Agricultural Research (CIRAD), SAREC, the Commonwealth Scientific and Industrial Research Organization (CSIRO), and the Universities of Florida and Sussex.



THE CHALLENGE

By the year 2025¹ there will be about 8.5 billion people on the planet, of whom some 7 billion will be living in the developing countries of Asia, Africa, and Latin America.² The questions we have to ask ourselves now are:

- Can we:
 - produce enough food to feed this population;
 - in a sustainable manner, without damaging the environment; and
 - ensure the food is accessible to all, so that everyone receives at least an adequate diet?
- Should we, and can we:
 - enable developing countries to meet most of their own food needs; and
 - ensure that agricultural production is more effectively linked with economic and social development?

¹ We have chosen the year 2025 as our future reference point for a number of reasons: we know with reasonable accuracy the size of the world population and the amount of food they will need; 2025 lies within the lifetime of most of the people on this planet alive today; and, 2025 lies within the lifetime of many, if not most, of those who currently make or influence national and global policies.

² In the document we distinguish between “industrial countries” and “developing countries.” The latter encompass a great variety of countries from those with GNP per capita exceeding US\$2,000 in the newly industrialized countries to the poorest countries in the world with GNP per capita below US\$250. The economies of all these developing countries can be expected to change, some markedly, by the year 2025, but for ease of comparison we assume that countries remain in the same categories (of the technical annex by Peter Hazell, IFPRI). [See Appendix II, page 72.]

In addressing these issues, we need to consider the role of agricultural research:

- private and public;
- international and national; and
- collaborative.

In this document we attempt to provide answers to these questions, as far as we are able, and to outline an agenda for action, focusing primarily on the role of the CGIAR and its centers.

Our conclusions are that the world population in 2025 can be adequately fed, malnourishment can be eliminated, and this can be achieved in a way that prevents environmental degradation and conserves natural resources. We believe, however, that this can only be accomplished if there is significant investment in public research, both national and international, involving the CGIAR System in partnership with NARS, on a commonly agreed set of programs.

Who Are the Hungry?

Globally we produce enough food for everyone to be adequately fed, yet hunger is common. More than 700 million people in the developing world do not have access to enough food to live healthy and productive lives; they often go hungry not knowing when they will have their next meal. More than 180 million children are underweight. Vitamin A deficiencies are widespread and growing. Malnourishment is contributing to at least one-third of child deaths.

Most of the poor and malnourished live in rural areas. They tend to be landless or are unable, on the land available to them, to create a food-se-

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cure livelihood.³ They are commonly women and children, often in female-headed households. The poor also live in urban areas, and their numbers are growing rapidly.

Paradoxically, hunger is common despite a period of rapidly declining world food prices. Low food prices should be beneficial to the hungry, since they mostly depend on the market for food. However, they lack sufficient income to purchase enough food for their needs. In 1990, more than 1 billion people were living on less than US\$1 a day in developing countries.

What Are Their Prospects?

If nothing is done, the numbers of poor and hungry will rise rapidly. While global population growth rates have declined from a high of 2.1 percent a year during 1965 to 1973 to 1.6 percent in the 1990s, the size of the current annual increment is unprecedented. Until well into the next century, approximately 100 million people will be added to the world population each year. By the year 2025 the population of the globe will be about 8.5 billion, of whom 7 billion will be in developing countries. [See Figure 1, page 65.]

Over half of this population will live in urban areas. They and the rural population will have to depend on a declining area of cropland per person and declining access to forests, range-

lands, fisheries, and other natural resources. In Asia, the currently 0.15 hectares of cropland available per capita will fall to a mere 0.09 hectares in 2025. Africa will apparently fare better; but, the quality of the land is generally poorer than in Asia, with less potential for irrigation.

More than half of the developing world's poor are in South Asia and Sub-Saharan Africa, and the numbers are growing at an alarming rate. The population of South Asia will have grown to about 2 billion, but the highest growth rates are in Sub-Saharan Africa. From the current 500 million, the African population will grow to 1.2 billion. Population growth in Africa will outstrip growth in food production for a long time to come unless much more is done to accelerate agricultural growth. If current trends continue, by the year 2025 Africa could well have an annual food gap of 214 million tons⁴ (this compares with current imports of 11 million tons).

It will take a long time before African countries can generate sufficient foreign exchange to purchase such large amounts of food. The real prices of Africa's traditional export crops are low and declining, and the non-agriculture sector is small. It is also unlikely that African governments will be able to count on enough food aid to make up the difference. All indicators concur that poverty, malnutrition, and hunger will increase rapidly in the coming years unless action is taken to dramatically increase agricultural production

³ A "livelihood" is a means of living, and the capabilities, assets, and activities required for it. A "food secure livelihood" provides access at all times to the food required by a household for a healthy and productive life by all of its members. Households may grow sufficient food or may purchase the food they require by earning income through selling agricultural products or engaging in agricultural or non-agricultural employment.

⁴ In this document we define the "food gap" as the cereal-equivalent requirement to meet the energy "need" of the population less the sum of domestic consumption and imports. The "need" assumes a minimum of 3,000 cereal calories per person per day to cover food, livestock feed, seed, storage losses, and processing waste. [See Appendix II, page 72.]

through technological change that also increases agricultural employment.

While not as badly off as Sub-Saharan Africa, there are disquieting trends in South Asia. Yields are increasing at a slower rate than they did in the past three decades. Growth in Asian rice yields, for instance, has slowed from an annual rate of 3 percent in the late 1970s and early 1980s to less than 2 percent during the late 1980s. Total market demand for cereals is likely to increase to an annual 400 million tons by 2025, with an additional 210 million tons required to eradicate hunger. Total cereal production is only likely to increase to 355 million tons by 2025, and even less if yield growth rates continue to slow. The potential cereal need gap could, therefore, reach 255 million tons by 2025.

Although exports of manufactured goods are likely to rise more rapidly in South Asia than in Sub-Saharan Africa, it still will not have sufficient foreign exchange earnings to purchase the needed volume of cereals, even if it was available on the market.

Why Should We Be Concerned?

Over 2 billion people in the world regularly watch television. For the rich, the images on their screens provide a constant reminder of the horrors of natural disasters, civil war, and famine. For the poor, the screens portray the everyday luxuries of the affluent and well-fed. Globally, the consequence is a potentially explosive mix of fears, threats, and unsatisfied hopes.

The end of the Cold War has not brought about an increase in political

stability. While conflict between East and West has declined, there is a fast growing divide between the world of the peoples, countries, and regions that “belong,” in global power terms, and those that are excluded. Confronting the increasing globalization of government, capital, technology, and trade are the surging expectations of the poor.

Yet this growing conflict receives relatively little attention in industrial countries. The severe economic recession and the end of the Cold War have made political agendas inward-looking. Governments struggling with record-high unemployment, rising costs for welfare payments, growing budget deficits, and political polarization are paying little attention to the needs of poor nations overseas. The volume of aid going to developing countries is stagnating in real terms. The attention the industrial world is giving to external problems is being focused increasingly on the former Eastern Bloc countries.

Reductions in aid may be justifiable in the short-term, but, we would argue, are not in the long-, and even the medium-, term interest of industrial countries. An increasingly polarized world will result in growing political unrest. Already the consequences of economic stagnation, population growth, environmental degradation, and civil war are producing unprecedented movements of peoples. There are currently some 14 million refugees in need of assistance living in foreign countries and at least double that number who are refugees or displaced persons within their own countries. Unless developing countries are helped to realize sufficient food, employment, and shelter for their growing populations, or to gain the means to purchase food internationally, the political sta-

All indicators concur that poverty, malnutrition, and hunger will increase rapidly in the coming years unless action is taken to dramatically increase agricultural production through technological change that also increases agricultural employment.

Justice and equity also demand that poverty be eliminated. Moreover, it is a goal within our capacity. Globalization, while threatening on the one hand to concentrate power and increase division, on the other contains the economic and technological potential to transform the lives of the rich and poor alike.

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Justice and equity also demand that poverty be eliminated. Moreover, it is a goal within our capacity. Globalization, while threatening on the one hand to concentrate power and increase division, on the other contains the economic and technological potential to transform the lives of rich and poor alike. Much depends on where our priorities lie and, in particular, whether there is sufficient access by the poor to the economic opportunities created by the products of new technologies. Here, as we will argue, international agricultural research has a particularly crucial role to play.

FOOD PRODUCTION PROSPECTS

What Are the Current Trends?

While a significant proportion of the growth in cereal production since the 1960s has come from the expansion of arable land, yields of major cereals have more than doubled in the past three decades. On past trends we ought to be able to continue to match the rising population with a comparable increase in food production on existing arable land, at least to the year 2025.

There are, in theory, no major physiological, genetic, or agronomic constraints to achieving the necessary yield gains. Conventional plant breeding techniques, increasingly augmented by genetic engineering, should be able to produce improved plant types capable of significantly higher yields in all parts of the world. There is considerable potential for increased and more efficient fertilizer use. Although appli-

The Challenge of Globalization

Traditional patterns of governance are being eroded. The supremacy of notional governments is being challenged from within by ethnic and religious groupings and from outside by supranational institutions, such as the International Monetary Fund, the World Bank, GATT, and the European Union. At the same time, NGOs are beginning to operate globally, pressing for citizens' rights, more development aid, and the elimination of poverty.

Capital is increasingly invested on a global scale. Multinational corporations are growing in power as capital becomes more mobile and financial markets are deregulated. In many parts of the world this opens up new economic opportunities; in others, perceived as poorly endowed with human and physical resources, there is little investment. While the economies of the newly industrialized countries of East Asia grow apace, much of Sub-Saharan Africa stagnates or is in decline.

Modern technology and the accompanying research and development are now disseminated through global communications and multinational research networks. Much is in the hands of multinational corporations, yet many powerful advanced technologies are often small in scale, readily transferable and become increasingly inexpensive with mass use.

Trade now operates through a great variety of global markets. While trading blocks such as the European Union continue to prevent easy access of goods from developing countries, current GATT negotiations are likely to create new opportunities for manufactured goods and agricultural exports.

cation rates are relatively high in those regions where the green revolution has occurred, the average in Asia is still only 30 kilograms of nitrogen per hectare, in Latin America it is 15 kilograms and in Africa 4 kilograms. This compares with national averages of 120 to 550 kilograms for the industrial countries of Western Europe, Japan, and China.

Equally significant is the potential for improving the supply of water through irrigation and various means of water conservation. Between 1960 and 1990 the area under irrigation grew from 100 to 170 million hectares. It is estimated that irrigated land in developing countries could be expanded by nearly 60 percent, with most of the potential in India, China, and other countries in Asia. However, in recent years there has been a significant decrease in the rate of expansion of irrigation as real costs of irrigation projects have risen.

Are the Trends Sustainable?

The desire for food security has left its mark on the environment, sometimes permanently. Hunger leads to desperate strategies for survival, and attempts to meet basic needs often take precedence in the short-term over longer-term sustainability. The blame should not be placed on the poor and hungry. Exploitation of resources by the rich, unsuitable agricultural technologies, and lack of appropriate institutions and governmental policies have combined to damage both well-favored and environmentally-fragile lands.

Globally about 2 billion hectares of soil, of which 1.5 billion lie in developing countries (17 percent of all vegetated areas), have become degraded due to human action since 1945. Degradation includes water and wind

erosion, loss of soil nutrients, salinization, acidification, pollution, compaction, waterlogging, and subsidence. Most, but not all, results from inappropriate agricultural practices. Lack of terraces, failure to replace nutrients and organic matter, and excessive irrigation or drainage are damaging arable land. Rangeland is being degraded by overgrazing. Whether or not agriculture is a cause, soil degradation severely limits agricultural productivity. In some cases reclamation is bio-physically impossible. In others, the costs are high, but reclamation can be achieved with labor, ingenuity, and new technologies.

Other natural resources which also contribute directly or indirectly to food security are also being lost at unprecedented rates. The annual rate of destruction of closed forests is about 16 million hectares each year. This represents a substantial loss of potential income and employment from the sustainable harvest of timber, firewood, and other non-timber forest products. Forest destruction is also one of the prime causes of the increasing loss of global biodiversity. An estimated 15 percent of the world's plant and animal species could become extinct by 2025, many with potential for agricultural or forest exploitation.

Competition for water for agriculture has increased dramatically during the past two decades due to rapidly growing domestic and industrial demands. This situation will worsen through much of Africa and the Middle East by 2025. Significantly, the earlier high rates of expansion of irrigation appear to be unsustainable. Their continuation could exhaust irrigation potential in Asia well before 2025, would require an investment of US\$500-1,000 billion, and would face formidable

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technological environment and social constraints. A more feasible approach, especially for Sub-Saharan Africa, is through small-scale harnessing of water, but this requires appropriate incentives and institutions, coupled with new skills and technologies. More generally, greater emphasis will have to be given to improved management of irrigation systems.

The global harvest of wild fisheries is estimated to have peaked at 89 million tons in 1989. For most wild fish stocks the harvest is stagnant or declining as a result of overexploitation, pollution, and the use of fishing practices that damage the environment. Partial compensation is coming from aquaculture, which contributes 12 million tons a year and is growing at 10 percent, but its sustainability is threatened by pollution and conflicts over the use of coastal ecosystems.

Increased agricultural production is also limited by pollution. Industry is often to blame, but agriculture may be a both culprit and a victim. In the intensively farmed lands of both industrial and developing countries, heavy fertilizer applications are producing nitrate levels in drinking water that approach or exceed permitted levels, increasing the likelihood of government restrictions on fertilizer use. Pesticides are also causing serious harm, particularly in developing countries. There is growing human morbidity and mortality while pest populations are becoming resistant and escaping from natural control.

While industry is the major source of global pollution, agriculture is a growing contributor, producing significant levels of methane, carbon dioxide, and nitrous oxide.

Individually, or in combination, these gases and their products are contributing to global warming, the depletion of stratospheric ozone, acid deposition, and the build up of ozone levels in the lower atmosphere. These will, in turn, significantly affect agricultural production. Global warming, for example, will have effects that vary with latitude. Heat and water stress at low latitudes, where most developing coun-

Global Pollution Caused by Agriculture

Methane. *Forty-five percent of global emissions are produced by paddy fields, the guts of livestock, and the burning of vegetation. Methane contributes to increased tropospheric ozone, to destruction of ozone in the stratosphere, and to global warming.*

Nitrous oxide. *About 1 to 3 million tons of nitrous oxide is produced per year from nitrogen fertilizers, livestock waste, and the burning of vegetation. Levels are rising at about 0.2 to 0.3 percent per year, mostly driven by fertilizer use. Nitrous oxide, when converted to nitric oxide, contributes to the depletion of stratospheric ozone and to global warming.*

Carbon dioxide. *Burning biomass on savannah lands, in swidden agriculture, and as part of the permanent conversion of forest to agriculture contributes the equivalent of a quarter to a third of carbon dioxide produced from burning fossil fuels. Carbon dioxide emissions are responsible for about half of current and projected global warming.*

Ammonia *rises from nitrogen fertilizer applications and the volatilization of livestock waste and biomass burning. It contributes to acid deposition.*

tries are situated, will result in significant losses in yield. However, in the middle and high latitudes, the combined effect of temperature increases and the direct physiological effect of higher levels of carbon dioxide is likely to result in higher yields. Current projections thus suggest yield increases in the temperate, industrial regions of the world, but significant reductions in tropical and subtropical developing countries, possibly on the order of 30 to 50 percent.

Are There Signs of Stagnation?

As a group, developing countries increased per capita food production by 13 percent during the 1980s, but some regions performed much better than the average and some much worse. East Asia is the star performer, increasing per capita food production by 22 percent during the 1980s. China's increase has been 35 percent. However, in Africa and West Asia there has been a continuing decline in per capita food production.

In 75 of the world's countries, less food per capita was produced at the end of the 1980s than at the beginning. In 15 countries per capita food production fell by 20 percent or more. In Asia, as a whole, the annual rate of increase in rice and wheat yields in the late 1980s was considerably less than in the 1970s and early 1980s. [See Figure 2a, page 66.] In Africa, yields are still apparently growing, but with wide fluctuations. [See Figure 2b, page 66.]

Particularly worrying is the evidence, as yet not well documented, of signs of stagnation in yield growth rates in those areas of developing countries where the green revolution had its greatest impact. In the Indian

Punjab, for example, yield growth is being threatened by worsening availability and poor management of water, coupled with exhaustion of micronutrients, salinization, and build up of pests and diseases.

On a global scale, grain production per person has shown signs of stagnation if not a slight decline since 1985. [See Figure 3, page 67.] There have also been significant declines in non-cereal staples. In the 1980s per capita production of roots and tubers in developing countries fell by over 7 percent. There was a similar decline in production of plantains, and per capita banana production barely increased.

While per capita production of meat, milk, and other livestock products is continuing to increase in developing countries, per capita fish production is set to decline over the next 30 years unless aquaculture begins to grow at a much faster rate.

What is Forecast?

Total cereal market demand in developing countries for food and feed is projected to double to 2 billion tons by 2025. This estimate, it should be stressed, does not include the hidden needs of the poor who will be priced out of the market. In a well-fed world, another 400 million tons of cereals would likely be required, bringing the total cereal need in developing countries to 2.4 billion tons by 2025.

If recent yield growth rates for cereals continue to 2025, then total cereal production in developing countries will increase to 1.7 billion. This will leave a shortfall of 0.7 billion tons, over half occurring in South Asia and Sub-Saharan Africa. By 2025 the food need in South Asia will be 70 percent greater

Particularly worrying is the evidence, as yet not well documented, of signs of stagnation in yield growth rates in those areas of developing countries where the green revolution had its greatest impact.

than food production, and in Sub-Saharan Africa two and a half times as much. If the environmental constraints turn out to be as severe as some predict, and if the technologies are not available to deliver continuing yield growth rates, then these shortfalls could become even larger.

TWO SCENARIOS

If our analysis is correct, we can envisage two contrasting scenarios:

Scenario 1. Some industrial countries continue to produce food well in excess of their requirements and export this excess to meet the demand of developing countries. If it is assumed that the environmental constraints to increased food production can be overcome, and if the food needs of the poor are ignored, then there is little cause for concern. The food demands of developing countries, as expressed in national and international markets, will be met by national production in the areas of proven potential and by trade or aid from industrial countries. On present estimates this would entail some 300 million tons of cereals being sold to developing countries by the industrialized world in 2025, at today's world prices.

If the food needs of the poor are not ignored, then under this scenario, a further 400 million tons would be required in 2025 as subsidized or free food aid. This is equivalent to over 20 times the current supply of direct food aid and would cost some US\$44 billion (1988 prices). Such massive food aid would place heavy burdens on developing countries, particularly on the infrastructure for the receipt and distribution of the aid. It is also likely to depress local prices and add to exist-

ing disincentives for local food production.

To meet their own market demand and that of developing countries, and to provide the necessary food aid, industrial countries would have to at least double food production by the year 2025, from 860 million tons to 2 billion tons. This would necessitate considerable increases in yields per hectare and the bringing back into production of currently uncultivated land. Inevitably the environmental costs of such a scenario would be high.

A more fundamental objection to this scenario is that a significant portion of the population in the developing world would fail to participate in global economic growth.

Scenario 2. The developing countries greatly increase their own food production so as to largely meet their own needs, including the needs of the poor, investing in agricultural development as part of a larger development process.⁵ An alternative scenario envisages a rapid and broad-based growth in the developing world, not only in food production, but in agricultural and natural resources production generally. This scenario explicitly recognizes that food security is not simply a matter of producing enough food. It also depends on employment and incomes. Most of the world's hungry and food insecure are rural based. If they are not growing enough food to meet their needs, they must have the means to purchase the food they require, and hence are dependent on

⁵ Agriculture and natural resources use are inextricably related. In the following, therefore, agricultural development is throughout understood to mean the development of agriculture and natural resources, including forestry and fisheries; agricultural research means research in agriculture and natural resources.

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rural employment and income created by agriculture and the development of natural resources. Agriculture, forestry, and fisheries are powerful engines of development. Increased production and employment in these sectors can generate considerable employment, income, and growth in the rest of the economy.

Very few countries have experienced rapid economic growth without preceding or accompanying growth in agriculture. Those countries who have achieved the most rapid agricultural growth in the past 20 years also have had rapid economic growth. Countries with real declines in agriculture have had the lowest growth rates in the economy.

The development of agriculture is, moreover, central to the challenge posed by population growth. Experience indicates that decline in birth rates is crucially dependent on food and income security, coupled with education and enhanced earning opportunities for women. Such opportunities can be provided by the production, processing, and trading activities generated by broad-based agricultural and natural resources development.

Environmental protection and conservation is also crucially dependent on appropriate agricultural and natural resources development. Sustainable approaches to food production and to forestry and fisheries management can reverse land degradation and pollution from agrochemicals, remove pressure on national parks and reserves, conserve biodiversity, and, at the same time, increase food security.

In summary a major investment in agriculture and natural resources in developing countries could:

- create employment and incomes for the mass of the poor;
- deliver food security;
- help to reduce birth rates through increased food and income security;
- protect and conserve the environment;
- stimulate development in the rest of the economy; and
- ensure prosperity in the industrialized world through the stimulation of global trade and an increased likelihood of political stability.

THE WAY AHEAD

What is Needed for Agricultural Development?

There is no single recipe for successful agricultural development, though there is a broad consensus on many of the essential ingredients. These include: an enabling policy environment that does not discriminate against agriculture, forestry, or fisheries; liberalized markets for farm inputs and outputs, with major private sector involvement; efficient rural financial institutions; adequate rural infrastructure; and effective institutions to develop and disseminate appropriate agricultural technologies.

Making sure that agricultural growth contributes to poverty alleviation, equity, and food security requires:

- the creation of employment for the land poor and landless;
- increased production on small, medium-sized, and large farms; and
- attention to regions of varying agroclimatic potential, not just the best.

Agriculture, forestry, and fisheries are powerful engines of development. Increased production and employment in these sectors can generate considerable employment, income, and growth in the rest of the economy.

The scope of bringing further land and water resources into production is now limited, and future growth will depend more and more on increasing the productivity of already utilized resources.

Instruments for achieving these goals include appropriate targeting of agricultural research and extension; ensuring adequate access by all types of farmers to credit, inputs, and marketing services; investments in rural education, clean water, health, family planning, and nutrition programs to improve human resources; attention to women's needs and legal rights; and, in some cases, land reform or redistribution.

The relative importance of these requirements is complex and country specific, but recent experience is clear on two counts. First, while economic liberalization within developing countries and reform of international trading policies are necessary prerequisites for significant agricultural growth, they are not sufficient. Accelerated growth in agricultural output cannot be maintained without adequate investments in rural infrastructure and in agricultural research and extension. Indeed without such investment the results of liberalization policies may well fall short of expectations and set governments against market-oriented approaches.

Second, investments in agricultural research to generate new technologies and knowledge continue to give consistently high rates of return. This has been demonstrated time and time again in ex post cost/benefit analyses of individual research projects and programs. It also emerges from time-series analyses of the sources of growth in factor productivity in agriculture for individual countries.

What Are the Research Priorities?

High economic returns to agricultural research occurred during an era when new land and water resources

were still being brought into production in many developing countries. The scope for bringing further land and water resources into production is now limited, and future growth will depend more and more on increasing the productivity of already utilized resources. Moreover, the benefits from agricultural research have still to reach large numbers of poor and hungry in the world.

Many of the past successes in research were due to concentration on high-potential areas (usually irrigated) and generic technologies that had widespread application (e.g. the high yielding varieties of rice and wheat). Such research must continue if the food demands of the escalating urban populations are to be met. Yet, in the future, achieving higher yields alone will not be enough; they have to be produced more cheaply and in a more sustainable manner.

In summary, future research on high-potential areas should be aimed at:

- higher yields per hectare;
- at less cost;
- with less environmental damage; and
- coupled with research on pricing, marketing, and distribution policies that ensure that the poor gain.

Research should also address the needs of the many rural poor who are landless or poor laborers living in the well-endowed, high agricultural production lands, providing it produces technologies that generate greater employment. The majority of the rural poor live in areas that are resource poor, highly heterogeneous, and risk prone. Agriculture here is limited by lower rainfall and less potential for irrigation, or steep slopes or poor soil structure, or lack of macro- or micro-

nutrients, or the presence of salts and other toxic compounds, or some combination of these. The yield response to research may be lower and the costs may be higher because of greater site specificity of the results, yet the benefits to the rural poor can be considerable.

This second type of research will be more complex, aimed at improving farming systems rather than specific commodities, with less reliance on the exploitation of resources originating outside the farm—fertilizers and pesticides. Such resources are often costly and sometimes unreliable, and frequently contribute to environmental degradation. They will continue to be essential if even higher productivity is to be attained. Equally, more attention will need to be paid to better use of resources internal to the farm. These are the under-recognized natural resources of agriculture, forestry, and fisheries:

- the natural parasites and predators of pests;
- algae, bacteria, and green manures that supply nitrogen;
- agroforestry and cropping systems that reduce erosion;
- underexploited wild tree and fish species; and
- genetic systems that increase tolerance to salts and toxins.

Inherently these are inexpensive resources, yet with skill and ingenuity they can be used to generate higher productivity on a sustainable basis.

Such research will also require greater involvement of farmers and local communities in research design. Because of the complexity of the problems and the site specificity of results, the initial focus should be on

developing methods and approaches, and in demonstrating successes at case study sites.

In summary, future research on areas with relatively lower potential should be aimed at:

- higher yields per hectare;
- at very low cost;
- making maximal use of indigenous resources—physical, biological, and human;
- on a sustainable basis; and
- coupled with research on improving the livelihoods of rural poor households through agriculture and agriculturally related income and employment generating activities.

Using Natural Enemies to Kill Pests

Research showed that the damaging outbreaks of the brown planthopper on rice often were due to the pesticides which killed off the spiders and other natural enemies of the planthoppers. Farmers were trained to recognize and regularly monitor the pests and their natural enemies. They then used rules to determine the minimum necessary use of pesticides, reducing the average number of sprayings per season from over four to one, while simultaneously increasing yields from 6.1 tons to 7.4 tons per hectare.

A “Doubly Green” or “Super Green” Revolution

The agricultural research challenge for the future is complex and demanding. Research must continue to assist the intensification of high-potential areas, albeit on a more environmentally-friendly basis. At the same time,

The majority of the rural poor live in areas that are resource poor, highly heterogeneous, and risk prone.

The agricultural research challenge for the future is complex and demanding. Research must continue to assist the intensification of high-potential areas, albeit on a more environmentally-friendly basis. At the same time, more research will be needed in lower-potential areas, where rural poverty and associated resource degradation is and will increasingly be concentrated.

more research will be needed in lower-potential areas, where rural poverty and associated resource degradation is and will increasingly be concentrated. The amount of additional agricultural output required will be large, more than doubling in South Asia and Africa by 2025.

In effect we require a revolution that is even more productive than the first green revolution and even more “green” in terms of conserving natural resources and the environment, a “doubly green” or “super green” revolution.

Over the next three decades it must aim to:

- repeat the successes of the green revolution;
- on a global scale;
- in many diverse localities; and
- be suitable, sustainable, and environmentally-friendly.

While the first green revolution took as its starting point the biological challenge inherent in producing new high-yielding food crops and then looked to determine how the benefits could reach the poor, this new revolution has to reverse the chain of logic, starting with the socioeconomic demands of poor households and then seeking to identify appropriate research priorities.

In essence the new priorities should be: food security; income and employment generation; and conservation of natural resources and the environment, whose outcome is the creation of sustainable livelihoods for the poor.

We Need to Exploit New Research Paradigms

The successful breeding programs of the first green revolution relied on close collaboration between plant

breeders, geneticists, agronomists, plant pathologists, and entomologists. In the future, such multi-disciplinary project teams will need even greater integration and a wider span of disciplines, encompassing both the natural and social sciences.

Present day biological and agricultural research institutions are in a state of change. They have different profiles of operation than they had a decade ago. Two developments in science are driving these changes:

The first is the emergence of molecular biology, a discipline, with its associated technologies, which is now integrated into all biological research fields. Molecular biology is concerned with the sub-cellular basis of life. It has been transformed by the recent revolutionary advances in laboratory technologies which have greatly increased not only our understanding of sub-cellular and genetic processes, but also have created opportunities for their manipulation.

The immediate potential of molecular biology lies in the design and engineering of new plant and animal types required for both high- and low-input systems. Plant breeders have been able to overcome some major limitations to yield by selecting needed characteristics from germplasm resources. Good examples are genes providing resistance to insect pests (brown plant hopper in rice) and disease (rust in wheat), tolerance to environmental stresses (aluminum tolerance in wheat), changes in plant architecture (semi-dwarf wheats), and alternatives in plant development (photoperiod control of flowering time in soybean).

There are major problems for which plant breeders have not been

able to identify or introduce appropriate new genetic variation. The problems potentially amenable to solutions through genetic engineering include: resistance to viruses, insects, and herbicides; tolerance to salt, drought, and heat; crop reserve improvement (carbohydrates, proteins, and oils); and nitrogen fixation. DNA technologies are beginning to make an impact in some of these cases. The key developments have been the development of gene transfer technologies for most of the major crop and pasture species. Molecular biologists can now design and build gene constructs which can be inserted into the genetic tape of a target plant to provide the transgenic plant with a new trait (e.g. pest resistance). As a result, the plant breeder is no longer restricted to the genetic variation that arises in traditional breeding programs.

Such genetic engineering has special value for agricultural production in developing countries. It has the potential to provide built-in solutions to biotic and abiotic challenges, reducing the need for chemical inputs such as fungicides and pesticides. The seed, with its enhanced genetic instructions, is a "farmer-friendly software package," compatible with low-input agriculture and fitting the requirements of sustainability now placed on higher-input agricultural systems.

The second development is an ecological approach that, in tandem with economics, sociology, and anthropology, is rapidly increasing our understanding of the structure and dynamics of agroecosystems.⁶ Ecology is concerned with the interactions among organisms and between organ-

isms and their environments. In recent years it has been transformed by sophisticated field experimentation based on quantitative and qualitative system models.

Recent advances in population, community, and ecosystem research are providing a better understanding of the complex dynamics that arise within crop populations and in multiple-cropping and agroforestry systems. Practical applications include the development of integrated pest management systems, where the use of natural parasites and predators can be substituted for pesticide applications, often involving savings in costs and reductions in environmental damage.

Ecological thinking has also begun to inform understanding of the livelihoods of poor households, particularly in their patterns of response to environmental stresses and shocks. Such knowledge contributes to better practical appreciation of the ways small farmers and poor households can utilize specific agricultural technologies to enhance their livelihoods and render them more sustainable.

Perhaps the most important outcome of this partnership between ecology and the social sciences has been the development of new methods and, more importantly, new approaches and attitudes to the involvement of farmers themselves in the analysis of their farming systems and livelihoods. Simple, yet powerful, methods have been developed that encourage farmer analysis, design,

The immediate potential of molecular biology lies in the design and engineering of new plant and animal types required for both high- and low-input systems.

⁶ In this document we define an agroecosystem as "an ecological and socioeconomic system, comprising domesticated plants and/or animals and the people who husband them, intended for the purpose of producing food, fiber, or other agricultural products."

Perhaps the most important outcome of this partnership between ecology and the social sciences has been the development of new methods and, more importantly, new approaches and attitudes to the involvement of farmers themselves in the analysis of their farming systems and livelihoods.

and management of agricultural and natural resources systems in partnership with research scientists and extension specialists. These are now showing practical results in their application to varietal selection, the development of integrated pest management systems, the construction and management of small-scale irrigation, reforestation, and the conservation of watersheds.

These developments in molecular biology and ecology, at the core of the new interdisciplinarity of biological research, are having considerable impact on laboratory and field research. More importantly, they provide novel ways of thinking and inquiring about biological, agricultural and socioeconomic phenomena, bringing new system perspectives, and enhancing our capacity to define critical answerable questions. They are not alternatives. Indeed they are complementary, providing the means whereby farmers and field and laboratory scientists can collaborate in identifying and answering the research questions posed by the socio-economic needs of poor households.

INTERNATIONAL PUBLIC RESEARCH

Why Do We Need Public Research?

In industrial countries the production of new varieties and agronomic technologies has increasingly been assigned to the private sector. Better-off farmers, often heavily subsidized, are able to afford the products of expensive research. Private companies can patent and protect their discoveries for

Farmer Participation in Agricultural Research and Development

CIAT has established "innovators' workshops" in which farmers design and evaluate experiments. One experiment tackled the problem of lack of stakes for climbing snap beans. The farmers suggested growing the beans after tomatoes, thereby exploiting the tomato stakes and the residual fertilizer. Using various criteria of success that they devised, the farmers agreed on two snap bean varieties as outstanding for this system.

Collaborative research between IIMI and the Nepal Department of Irrigation has developed better methods for identifying hill irrigation systems with unrealized potential and participatory mechanisms in which farmers plan, design, and mobilize resources for the improvement of even quite large systems. The results are greater efficiency and sustainability of operation.

sufficient time to realize an acceptable profit.

Inevitably private research focuses on the major high-value crops, on labor-saving technologies, and on the needs of capital-intensive farming. By contrast research to feed the poor is less attractive to private interests, because:

- It frequently involves long lead times, for example in developing new plant types of minor staples.
- It is risky, particularly when focused on heterogeneous environments that are subject to high climatic and other variability.
- The beneficiaries have little capacity to pay for the research.
- The products cannot be restricted to those who pay, if they can.

- Intellectual property rights can rarely be protected.

Thus, while private research carried out by national and multinational companies has much to contribute to well-endowed lands and the better-off farmers, most of the needs of the poor will have to be met by public research agencies.

Public research also has a crucial role to play in ensuring that technologies are sustainable. Inevitably the beneficiaries of environmentally appropriate technologies are often not the users, or at least the users alone. In contrast to private research, where the benefits are captured by private companies and a limited group of users, public research aimed at low cost, sustainable food production has benefits that spread to farmers, large and small, to other rural dwellers and, most importantly, to poor consumers. Public agricultural research aims to exploit the potential for positive externalities, especially as they benefit the poor.

Why Do We Need a Continuing Effort in International Research?

The major problems of food security, poverty alleviation, and conservation of the environment that we have described above are not restricted to one country or region of the world. They affect, and will continue to affect, a major proportion of the world's population in many regions of Africa, Asia, and South America.

As yet, many of the countries worst affected still lack sufficient agricultural and natural resources research capacities to deal with their problems. The required research typically draws on many disciplines and production specialties, often lacking even in well-

developed NARS. An international research effort, involving partnerships between national and international centers, can help to remedy these deficiencies and provide outputs which have impacts that cross national boundaries. Often the problems are common and so are the solutions.

Thus, research activities that have significant economics of scale or scope are strong candidates for international agricultural research. In these cases, it is more cost-effective for individual countries to pool their resources and to conduct research on an international basis. This is especially true for small countries.

Second, research activities that involve important international externalities (such as spillover benefits or environmental costs and benefits) also have strong justification for international research. Since the costs and benefits of international externalities are not fully borne by the country that undertakes the research, there will be incentives to under- or over-invest in research when judged from the perspective of global welfare. For example, individual countries are unlikely to invest enough in research activities that have spillover benefits for other countries (e.g. germplasm that can be used in other countries), or that lead to reduced carbon emissions (e.g. sustainable forestry), which protect biodiversity, or prevent soil erosion into international waterways, because they do not capture all the benefits from the research.

Similarly, countries are likely to over-invest in research activities that indirectly promote deforestation or water pollution, if the environmental costs are borne by other countries. International agricultural research can

While private research carried out by national and multinational companies has much to contribute to well-endowed lands and the better-off farmers, most of the needs of the poor will have to be met by public research agencies.

International agricultural research can help correct for under-investment in globally appropriate research activities and for national over-investment in research activities that have negative environmental effects.

help correct for under-investment in globally appropriate research activities and for national over-investment in research activities that have negative environmental effects.

Third, international research can help strengthen NARS in the early stages of development and, in general, help improve the access of NARS to new knowledge and technology. This will ensure that NARS at all levels of development can benefit from the most recent advances in science and technology.

The NARS of developing countries encompass a wide range of institutions, varying in size and capability. From 1970 to 1990 many new public agricultural research institutes and universities were created. In the late 1980s public deficits gradually led governments to reduce research investment and operating expenses; as a consequence, many NARS have suffered major crises, the most severe in Africa.

One advocated solution was privatization. In practice this has proved difficult to achieve. There has also been slow progress in setting up farmer supported research organizations. Producer cooperatives, in various guises, have proved successful at the organization of inputs and marketing, but few have extended their remit to research. Success has been more apparent in the research programs funded and supported by national and international NGOs.

Despite the financial stringencies they face, industrial countries have continued to provide support to NARS through collaborative links involving their own universities and research centers. A few European countries have maintained public organizations for international agricultural research and

have recently set up the European Consortium for Agricultural Research in the Tropics (ECART). The United States has comparable programs, often involving the Land Grant universities, and funded by the U.S. Agency for International Development (USAID), Ford, Rockefeller, and other private foundations. Japan, Canada, and Australia have also set up institutions specializing in scientific cooperation. These efforts, however, are not well coordinated. Information circulates poorly, and there is little interaction between the different protagonists.

What is the Role of the CGIAR System in the International Effort?

Investments in the CGIAR constitute only 3 percent of annual public spending on agricultural research globally. Despite this small share, the CGIAR plays a key role in fostering the effectiveness and further development of the global agricultural research system.

For over 20 years the CGIAR has played a leadership role which stems from its scientific credibility and widely acknowledged achievements. The CGIAR is the only truly international, non-political agricultural research entity. The CGIAR has also served as a bridge between institutions, most notably between developing country research systems and advanced institutions in industrial and developing countries. Their knowledge of the conditions of NARS in various levels of development has enabled CGIAR centers to demonstrate best practices through networks, consortia, and other means, leading to greater South-South cooperation in research.

The CGIAR is an informal consortium of donors, encompassing national governments and international agencies, linked by the common purpose of eradicating hunger and poverty through research. To achieve this task it has created a family of 16 research centers. While each center has its own board and largely sets its own agenda, these conform to priorities and objectives determined by an independent TAC.

The essence of the CGIAR is independence, accountability, and research excellence, monitored and evaluated by external mechanisms. This provides a quality guarantee for donors who can make funding decisions within an analytical framework provided by a body that is independent of the ultimate recipients of support. Few institutions receiving aid funding can match this feature. These characteristics have contributed to a remarkable record of research achievement over the past 30 years, especially in germplasm characterization, plant breeding, pathology, pest control, crop, livestock, and agroforestry systems, and field application of new technologies of tillage and soil conservation.

In summary, the scientific and technological infrastructure of the CGIAR provides a unique capacity for focused research with worldwide application. From the donor and developing country perspectives the CGIAR provides public research of guaranteed high value, at relatively low cost.

A FUTURE FOR THE CGIAR

The Need for Change to a Program Based Approach

The problems of providing sustainable food security for all in a world

of rapid population growth are daunting in their complexity. They cannot be solved by the simple transfer of technologies, but require genuine partnerships operating at both global and regional levels. The research institutes of industrial countries, both public and private, and the national agricultural research institutes of developing countries need to be linked in new ways that reflect the opportunities created by the revolution in modern biology.

In the future, although the CGIAR's overall purpose will remain the same,⁷ its modalities of operation will need to change considerably if it is to meet these new challenges. Some of its key roles will require long term support and may well operate on a center base, but the CGIAR will need to increasingly focus on new and different partnerships that work toward well defined outcomes.

This will require changes in the strategic and operational planning and funding of the CGIAR System. A portfolio of programs, rather than reliance only on a set of centers, should constitute the business prospectus of the System and ultimately be the basis for fund allocation.

The justification for this program based approach is:

- The complexity of the challenge (realizing high, sustainable productivity at a cost that provides affordable food for the poor).
- The need to foster research partnerships that go beyond a simple transfer of technology.

⁷ Through international agricultural research and related activities, and in partnership with national research systems, to contribute to sustainable improvements in the productivity of agriculture, forestry, and fisheries in developing countries in ways that enhance nutrition and well-being, especially of low-income people.

Their knowledge of the conditions of NARS in various levels of development has enabled CGIAR centers to demonstrate best practices through networks, consortia, and other means, leading to greater South-South cooperation in research.

Participants in Potential Partnerships in International Agricultural Research

Industrial Countries

Research institutes
Universities
Private companies
Consortia

CGIAR

International agricultural research centers

Developing Countries

Regional research institutes
National research institutes
Universities
Private companies
NGOs
Farmers

-
- The opportunity to exploit the new paradigms (molecular biology and ecology), requiring interdisciplinary partnerships and links to advanced expertise.
 - The increasing focus on a wide range of agroecosystems necessitating greater in-country expertise and farmer participation in research.
 - The need to work to agendas of widely agreed research outcomes and outputs.

To operate in this context, the CGIAR will need broader-based advice on such issues as demography, natural resources, and food security, and be able to keep abreast of the developments and changing capabilities of modern biological science. So equipped, it can then formulate its agenda of collaborative programs within an overall agreed international agricultural research effort. One con-

sequence will be that programs will commonly have funds from a number of different sources, within and outside of the CGIAR, and will be limited in their duration.

The Underlying Principles for the Future

Three principles should apply in defining the CGIAR's specific responsibilities and roles within the international research effort:

- **Subsidiarity.** As a general principle, the primary responsibility for a research activity should be devolved to the lowest level in the hierarchy, from global to regional to national, that can carry out the activity most appropriately and efficiently.
- **Partnership.** In carrying out a research activity, partnerships with agencies with complementary skills and experience should always be considered as an alternative to adding capacities to CGIAR centers.
- **Transfer.** Even if there is no clear gain in efficiency or expertise from the involvement of developing country research institutions, the objective of strengthening developing country NARS justifies placing priority on their involvement with international research efforts.

The Nature of the Programs

Applying the principles, we can envisage the CGIAR as contributing to international research activities through two types of programs:

- Global programs
- Regional action programs

Global programs would be geared toward strategic research problems of international significance. **Regional action programs** would address specific sustainable production problems faced in significant geographic regions. It is important to differentiate these two types of programs because of differences in the scope of the problems to be addressed and the range of actors likely to be involved, both in funding and in executing the research effort.

The CGIAR would progressively channel all of its funding into a set of well-defined research programs. This is a departure from the present practice of funding international centers. In the future, institutes should be receiving funding from the CGIAR, but only for their involvement in one or more specific programs of interest to the CGIAR.

We suggest three types of global programs:

- long-term, center-based programs;
- multi-center programs; and
- collaborative strategic research programs.

Long-term, Center-based Programs

The CGIAR would provide funding to these programs on a continuous and stable basis. The centers would be fewer in number than at present. As a group, they would focus on the heartland of the CGIAR mandate and carry out programs which have a long-term perspective. The CGIAR would approve programs, and the allocation of resources to centers for carrying out these programs would be as at present. Existing CGIAR mechanisms would be used in the monitoring and evaluation of their implementation.

These center-based programs should be tailored toward resolving problems:

- in regions where increased production is needed most urgently (such as in Sub-Saharan Africa and South Asia); and
- in situations where public research is most required because of market failures, and where sustainability concerns are most pressing.

Such programs would focus primarily on the development of genetic materials for selected crop, livestock, forestry, and fish species that are recognized as providing keys to the solutions of these problems. In their funding and execution, long-term programs would be designed to preserve and enhance the intellectual capital and the intellectual heartland of the CGIAR centers.

Multi-center Programs

Some of the programs supported by the CGIAR would be carried out by all or a subset of the centers. These programs would be continuous or long-term in duration. They would be managed through an inter-center mechanism and would require funding from the CGIAR, except for services which should be financed by their users.

Illustrative examples of multi-center programs include:

- the conservation, characterization, and evaluation of selected germplasm;
- the provision of information, materials, and training in research methods and approaches; and
- advice on institutional strengthening and on food production, dis-

The CGIAR would progressively channel all of its funding into a set of well-defined research programs. This is a departure from the present practice of funding international centers.

tribution, and pricing policies for sustainable food security.

Collaborative Strategic Research Programs

These would focus on research problems which are global in nature and which cut across the core themes covered by the centers. The programs would be of a finite duration, usually a 5 to 10 year period. The problems covered would represent a “good investment risk” for the CGIAR and other partners funding them. The research would be carried out by a set of collaborating institutes, including CGIAR centers. One of these would assume leadership of the effort. Funding for the programs would come from the CGIAR as well as other sources. The effort would be evaluated by existing CGIAR mechanisms.

Illustrative examples of research themes that fall in this category include:

- decline in yields of major cereals in intensively cropped, cereal-based systems;
- development of small-scale irrigation and water conservation systems;
- improved understanding of key biological, physical, social, and economic dynamics of selected critical ecosystems, such as coastal zones;
- reduced productivity of global pollutants, especially nitrous oxide and methane, from agricultural practices; and
- development and understanding of user participatory approaches in the design and management of irrigation, forestry, and fisheries systems.

Regional Action Programs

These would be problem-specific research programs, of a shorter duration than global strategic research programs. Agendas would be set by NARS, regional organizations, and interested donors, in partnership. Funding would come mainly from sources other than the CGIAR, although the CGIAR could also contribute to funding. Leadership of the programs would normally be assumed by NARS or other agencies, but in some cases the CGIAR centers could be asked to play a leading role. Monitoring and evaluation of the effort would be by a special mechanism agreed upon by participants. The CGIAR could use its own internal mechanism to monitor/evaluate aspects of the program involving CGIAR funding.

The following illustrate outputs of possible regional action programs:

- better yielding crop varieties and agroeconomic systems appropriate to specific acid and mineral deficient soils in the savannas of Latin America;
- synergetic cropping and crop-livestock systems providing higher, more stable yields in the highlands of West Asia;
- more productive cereal-based farming systems in Eastern and Southern Africa;
- sustainable coffee and cocoa based farming systems in West Africa; and
- integrated aquaculture systems for coastal South and Southeast Asia.

In summary, we envisage a CGIAR which is a more open and collaborative system than at present; a CGIAR which leads the global international agricultural research effort by:

In their funding and execution, long-term programs would be designed to preserve and enhance the intellectual capital and the intellectual heartland of the CGIAR centers.

- analyzing problems;
- developing agendas;
- fostering partnerships; and
- providing independent advice and evaluation to achieve solutions to the problems.

The CGIAR of tomorrow should use a wider range of institutional modalities in fulfilling its mandate than at present. [See Figure 4, page 68.]

CONCLUSIONS

Over the next 30 years the challenge we face is to:

- meet the food needs of the more than 700 million who go hungry today;
- provide food at affordable prices for almost 100 million more people every year (the largest annual population increase in history);
- increase production through greater productivity per unit of land (expansion in area is no longer feasible in most of the world); and
- do this in such a way as to conserve and not degrade natural resources and the environment.

These are challenges for the world community as a whole, not just the countries where the poor live. It is not simply a matter of justice and equity. The world is more interdependent than ever before. The growing globalization of institutions, ideas, capital, technology, and trade, and the opportunities created by the advances in information technology, are creating a world in which events in one country or region affect us all. Unless addressed smartly and in advance, poverty and hunger could lead to political destabilization and environmental destruction, with worldwide implications.

We have a collective responsibility to eradicate hunger from the face of the Earth in ways that protect our common environment. It is not simply a matter of meeting the market demand for food. The new mandate is to assure food security for all the world's population, through agricultural research that not only adds to food production but generates employment and income that, in turn, increases the market demand for food.

The panel believes we should turn to science for help—help in creating a new agricultural revolution, one that is global, equitable, sustainable, and environmentally-friendly. Science can meet this challenge, because new paradigms in science, particularly in molecular biology and ecology, are providing a better understanding of the complex interactions between physical, biological, and social systems, and are helping to create the tools and technologies needed to address the problems we face.

Mobilizing science in this way means significant investments in public research, both national and international. Because many of the problems that need to be researched are common across countries and regions, an international research effort is likely to be more efficient and productive. We advocate the creation of a global agricultural research system that links a range of institutions with one another in new partnership modes.

As the only truly global, apolitical public international agricultural research system today, the CGIAR has a special role to play in the evolution of such a system. It should lead in the identification of research problems of international significance, in the design of research programs, and in the as-

We have a collective responsibility to eradicate hunger from the face of the Earth in ways that protect our common environment.

If these recommendations are adopted, we believe that, with adequate support from the donor community, the CGIAR can spearhead a new global movement to ensure sustainable agriculture for a food secure world.

assessment of the impact of the overall global effort.

To do these things, the CGIAR will need some adjustments, both in the problems it directly addresses and in the modalities it uses to implement research programs. It should focus primarily on strategic research problems of global significance, through long-term, institute-based programs, multi-institute programs, and collaborative strategic research programs.

At the same time, the CGIAR should also participate in regional action programs, to a lesser or greater extent, depending on the strengths and needs of its developing country part-

ners. Here the CGIAR would play a bridging and catalytic role, but the leadership should rest with national or regional institutions. The current emphasis on funding core programs of an exclusive set of research centers should give way to funding programs, carried out in collaboration with developed and developing country institutions.

If these recommendations are adopted, we believe that, with adequate support from the donor community, the CGIAR can spearhead a new global movement to ensure sustainable agriculture for a food secure world.



Figure 1: Population by Regions, 1990 and 2025

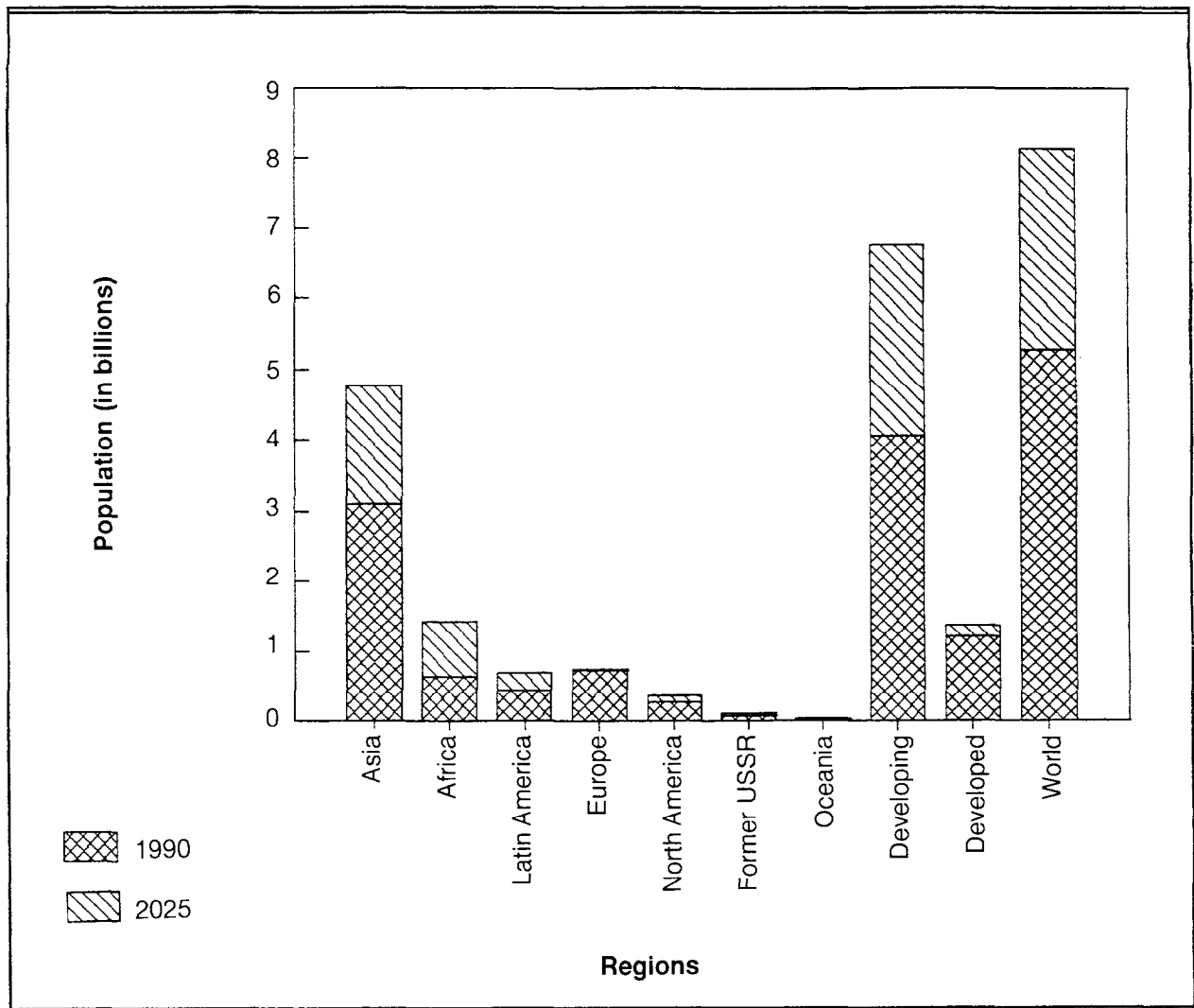


Figure 2a: Crop Yields in Asia 1961 to 1991: Composite of Maize, Rice, and Wheat

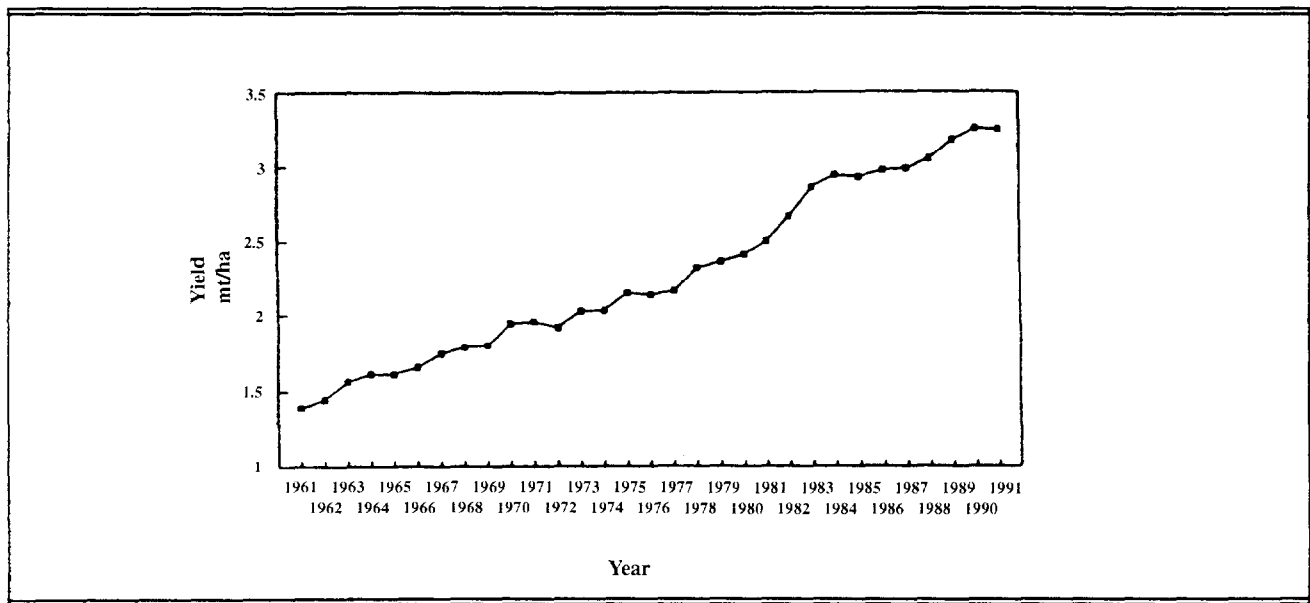


Figure 2b: Crop Yields in Africa 1961 to 1991: Composite of Maize, Rice, and Wheat

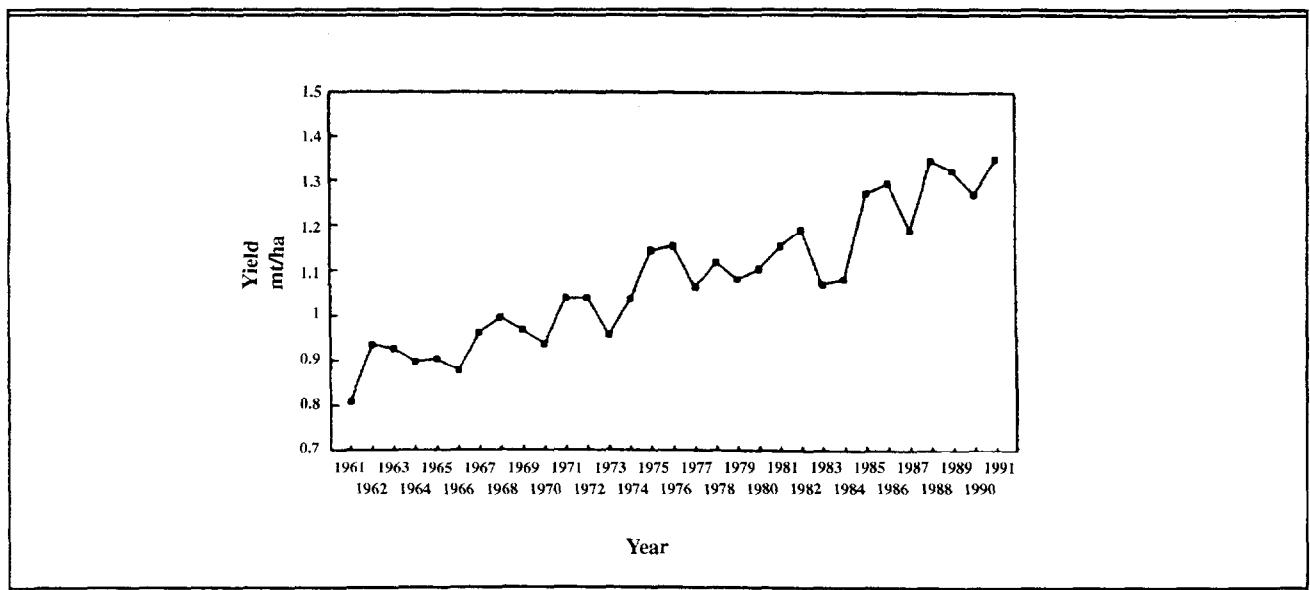


Figure 3: World Grain Production per Person, 1950 to 1993

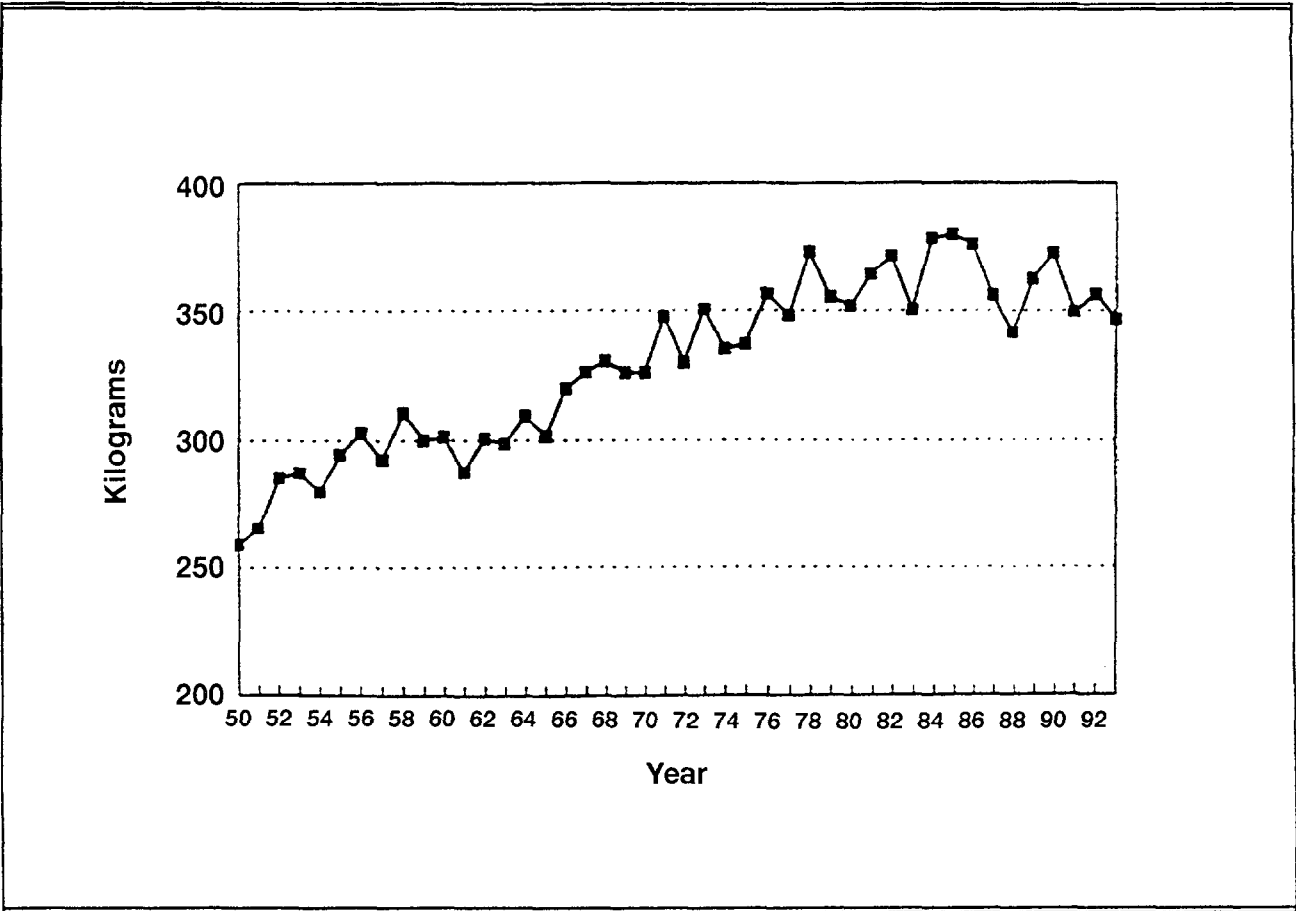


Figure 4: Suggested Programs and Their Features

Features	Global Programs			Regional Action Programs
	Long-term Center-based	Multi-center Strategic Research	Collaborative	
How long?	Continuous	Continuous or long-term	Finite (e.g. 5 to 10 years)	Finite (e.g. 5 to 10 years)
Who decides?	CGIAR	CGIAR	- CGIAR - Partners	Partnerships of donors and countries
Who funds?	CGIAR	- CGIAR - Users of services - Other sources	- CGIAR - Other sources	- CGIAR - Other sources
Who leads?	Center	Inter-center mechanism	One of the collaborating institutes (including CGIAR Center)	<i>Ad hoc</i> arrangement (e.g. NARS or other organizations)
Who evaluates?	Existing CGIAR mechanisms	Existing CGIAR mechanisms	Existing CGIAR mechanisms	- Social mechanisms agreed to by participants - Existing CGIAR mechanisms for the CGIAR component

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APPENDIX I ABOUT THE PANEL

Gordon Conway, Chair

Gordon Conway, of the United Kingdom, is Vice-Chancellor of the University of Sussex (since 1992), Chair of the Board of the Institute of Development Studies, and a Member of the Global Environmental Change Committee of the Economic and Social Science Research Council. Prior to his current appointment, he was Ford Foundation Representative for India, Nepal, and Sri Lanka, based in new Delhi. Earlier he was Professor of Environmental Technology at the University of London and Visiting Professor at the University of Chiang Mai, Thailand. Gordon Conway has a PhD in Systems Ecology from the University of California, Davis, Diplomas in Agricultural Science (University of Cambridge), and Tropical Agriculture (University of the West Indies, Trinidad), and B.Sc. in Zoology from the University College of North Wales, Bangor, UK.

Uma Lele

Uma Lele, an Indian national, is a Graduate Research Professor of Food and Resource Economics at the Institute of Food and Agricultural Sciences, University of Florida, Gainesville; she also serves as Director of the Global Development Initiative of the Carnegie Corporation and the Carter Center. Prior to her move to Florida in 1991, she held various positions at the World Bank in Washington, D.C. (which she joined in 1971), most recently in areas of policy and development strategy. Uma Lele has a Ph.D. and M.S. in Economics from Cornell University.

W. James Peacock

Jim Peacock, an Australian, is Chief of the Division of Plant Industry of CSIRO, in Canberra, a position he has held since 1978. During his research career in CSIRO (which began in 1965), he has held a number of visiting professorships in biology, biochemistry, and molecular biology, including at Stanford University, the University of California, Los Angeles, and the University of Oregon. Jim Peacock is a Fellow of the Australian Academy of Science and the Royal Society of London. He obtained his B.Sc. and Ph.D. in Botany and Genetics from the University of Sydney.

Martín Piñeiro

Martin Piñeiro, of Argentina, is an independent consultant who recently completed two terms as Director General of the Inter-American Institute for Cooperation on Agriculture (IICA), from 1986 to 1993. Prior to that appointment, he was Research Coordinator at the Center for Social Research on State and Management, Argentina and, earlier, was Undersecretary (Vice Minister) of the Secretariat for Agriculture and Livestock in Argentina. Martin Piñeiro received his Ph.D. in Agricultural Economics from the University of California at Davis, M.S. in Agronomy from Iowa State University, and completed his undergraduate studies in Agronomy at the University of Buenos Aires.

Panel Secretary

Selçuk Özgediz, a Turkish national, is Management Adviser at the CGIAR Secretariat. He received his B.S. in economics and statistics from the

Middle East Technical University (Ankara), M.S. in mathematical statistics and M.A. and Ph.D. in Political Science from Michigan State University.

Resource Persons

Michel Griffon, of France, is Director of the Agricultural Policies and Forecasts Research Unit, and Chief Economist (since 1986), CIRAD, France. He is an agricultural engineer and economist, and studied Research and Development Economics at the University of Paris (DEA Degree Program).

Peter Hazell, of the United Kingdom, is Director of the Environment and Production Technology Division, IFPRI. He is an agricultural economist, with M.S. and Ph.D. degrees from Cornell University, and College Diplo-

mas in Agriculture and in Farm Management from Seale-Hayne Agricultural College, Devon.

Co-conveners on behalf of the CGIAR Oversight Committee

Henri Carsalade, of France, is currently on detachment from the Ministry of Agriculture to CIRAD, France, where he recently served as General Director (1990-1993). He is a Forestry Engineer and Agricultural Engineer, graduating from the Institute National Agronomique, France.

Johan Holmberg, of Sweden, is Director of Programmes of SAREC. He received his B.A. in Russian and English Languages and M.B.A. in Marketing Economics from Gothenburg School of Economics.



APPENDIX II
TECHNICAL ANNEX ON
PROJECTION METHODOLOGY

Peter Hazell
International Food Policy
Research Institute (IFPRI)

The projections of food production, demand, and imports for the year 2000 given in this document were derived from a global trade model developed by IFPRI, the International Food Policy and Trade Simulation Model (IFPTSIM). The model is fully documented in Agcaoili, Oga, and Rosegrant.⁸ IFPTSIM is a market equilibrium model of foodgrains and grain-fed livestock products that solves for prices, demand, production, and trade by major countries/regions and for the world. [See Table 1, page 74.] Population growth, income growth, and yield growth are all exogenous. [See Table 2, page 75.] However, growth in cereal production is endogenous because the cropped area is responsive to price. The model includes major livestock activities; hence, all cereal production, demand, and trade figures are aggregates of human food and livestock feed.

Cereal demand is endogenous and is driven by prices, income growth, and changes in the livestock sector. By definition, cereal demand for each region equals production plus imports less exports. At the global level, cereal demand equals production. There is no global cereal gap between market demand and supply because the endogenous price clears the market. The

hungry are simply priced out of the market, as in the real world.

Because this document is concerned about the prospects for a well-fed world, the model projections have been supplemented by side calculations of the additional cereals that would be needed in 2025 to meet the "hidden" food needs of the poor. The hidden need is calculated as follows. For each region, the amount of cereals required to supply 3,000 calories per person per day was calculated using the population projections for 2025. This level of caloric availability is assumed to be an acceptable minimum for meeting human food needs while allowing for livestock feed, seed, storage losses, and processing waste. The total amount of cereals required in a region to meet this minimum need is then compared with the projected market demand from the IFPTSIM model, and the difference is taken to be the "hidden" cereals need. For regions with a positive hidden need, the total cereals gap is taken as the difference between total food need and projected production. In all other cases, the projected cereals gap is taken as the difference between projected market demand and production, which equals projected imports in the IFPTSIM results.

These calculations of hidden food needs hinge critically on the required calorie level assumed. Our assumption of 3,000 calories per person per day for cereals supply is hardly generous for a well-fed world, but it still leads to food gaps of 214 million tons for Sub-Saharan Africa and 255 million tons for South Asia in 2025. Table 3 [see page 76] shows how these gaps change under different assumptions about the minimum calorie need. The gaps escalate enor-

⁸ Agcaoili, M., K. Oga, and M.W. Rosegrant. 1993. "Structure and Operation of the International Food Policy and Trade Simulation Model (IFPTSIM)." Paper presented at the Second Workshop of the Rice Supply and Demand Project, IRRI, Manila.

mously as the calorie requirement is increased. In 1988, average calorie availability from cereals in Sub-Saharan Africa and South Asia was only 1,290 and 1,638 calories per person per day, but this was associated with consider-

able malnutrition and hunger. Even when hidden foods needs are calculated using 1,500 calories per person per day, this still leads to food gaps in 2025 of 34 million tons for Africa and 46 million tons for South Asia.



Table 1: Country/Region and Commodity Coverage in the IFPRI Model

Classification		Country/Region
Developed Countries		USA EC12 Japan Other Western Europe Canada Australia New Zealand Other Developed Countries Other Eastern Europe Former Soviet Union
Developing Countries	Latin America	Mexico Brazil Argentina Other Latin America
	Africa	Nigeria Other Africa
	Middle East	Egypt Other Near East
	Asian LDCs	India Pakistan Bangladesh Indonesia Tailand Malaysia Philippines Singapore South Korea China Other Southeast Asia Other South Asia Other East Asia
	Other	Other Developing Countries Rest of the World
Commodities	Crops	Wheat, rice, maize, other coarse grains, soybean
	Animal Products	Beef, pork, poultry, mutton and lamb, fluid milk, eggs

Table 2: Key Exogenous Parameters in the IFPRI Model

Annual Growth Rates (%)	Sub-						World	
	Saharan Africa	South Asia	Other Asia	WANA	LAC	Developing		Developed
Population	2.8	1.9	1.2	1.6	1.2	1.6	0.5	1.4
GDP	3.2	3.8	4.8	3.2	2.8	3.8	2.8	-
Yield:								
Wheat	2.3	1.9	2.1	2.0	1.8	1.9	1.6	-
Maize	2.0	2.0	1.7	2.3	2.0	1.9	1.6	-
Other Coarse Grains	2.4	2.0	1.3	1.6	1.3	1.8	1.2	-
Rice	2.2	1.9	1.6	1.6	1.8	1.7	1.3	-
Soybeans	0.7	2.2	2.3	2.3	2.2	2.2	2.0	-
Beef	2.1	1.6	2.4	3.0	1.5	1.9	1.1	-
Pigmeat	2.2	2.2	2.2	2.5	2.5	2.3	1.0	-
Sheepmeat	1.3	2.4	2.3	2.3	1.9	2.2	2.0	-
Poultry	3.4	1.5	2.2	2.8	1.8	2.2	1.2	-
Eggs	4.0	2.0	2.8	2.5	2.7	2.7	1.7	-

Table 3: Projected Gaps in 2025 for Different Assumptions about Hidden Needs

	Africa	South Asia	Other Asia	WANA	LAC	All Developing
Model Projections						
Production	144.7	355.9	801.4	148.6	237.2	1,687.8
Market Demand	173.6	401.6	882.5	262.3	273.6	1,993.6
Commercial Imports	28.9	45.7	81.1	113.7	36.4	305.8
Hidden Need (additional demand above market demand)						
1,500 calories per day	5.5	-	-	-	-	5.5
2,000	65.3	5.8	-	-	-	71.1
2,500	124.9	107.6	-	-	-	232.5
3,000	184.7	209.4	-	-	-	394.1
4,000	304.1	413.1	105.1	13.3	49.3	884.9
Total Gap (imports plus hidden need)						
1,500 calories per day	34.4	45.7	81.1	113.7	36.4	311.3
2,000	94.2	51.5	81.1	113.7	36.4	376.9
2,500	153.8	153.3	81.1	113.7	36.4	538.3
3,000	213.6	255.1	81.1	113.7	36.4	699.9
4,000	333.0	458.8	186.2	127.0	85.7	1,190.7

