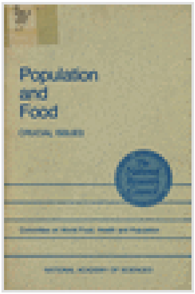

Population and Food: Crucial Issues (1975)

Pages
64

Size
5 x 9

ISBN
0309304687

Committee on World Food, Health, and Population;
National Research Council

Population and Food

CRUCIAL ISSUES

NATIONAL RESEARCH COUNCIL
COMMITTEE ON WORLD FOOD, HEALTH AND POPULATION

NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C. 1975

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Library of Congress Cataloging in Publication Data

National Academy of Sciences, Washington, D.C.
Committee on World Food, Health and Population.
Population and food: crucial issues.

Bibliography: p.
1. Food supply. 2. Population. I. Title.
HD9000.5.N335 1975 338.1'9 75-28423

Available from
Division of Biological Sciences, National Research Council
2101 Constitution Avenue, N.W., Washington, D.C. 20418

Printed in the United States of America

Foreword

For most of history, and certainly before, the adequacy of the food supply has been a principal preoccupation of mankind. In a general way, that food supply has increased more or less proportionally to the growth of human populations. But the extraordinary increase in the world population in the last few decades has significantly increased the vulnerability of that population in the event of agricultural failure. Meanwhile, American agriculture has assumed a unique position as the major single source of cereal grains and other commodities in international trade, the principal source of food aid to nations in distress, and a major repository of scientific agricultural technology.

Recognizing those circumstances, both the National Academy of Sciences and the National Science Foundation decided, in 1973, to undertake an examination of the prospects for the food supply and nutrition of the nations of the world, our own included. A distinguished committee, chaired by Dr. Daniel G. Aldrich, Jr., Chancellor of the University of California at Irvine, was asked to initiate this undertaking by examining the broader aspects of these problems.

A preliminary version of its report was made available to the Secretary of State and to the official members of the U.S. delegation to the World Food Conference in Rome in November 1974. The present statement may be regarded as introductory to a series of subsequent efforts. On December 3, 1974, President Gerald R. Ford requested the National Academy of Sciences " . . . in cooperation with the Department of Agriculture and other governmental agencies, . . . [to] make an assessment of this problem and develop specific recommendations on how our research and development capabilities can best be applied to meeting this major challenge."

A series of reports, responsive to this charge, may be expected to assist in the development of United States programs and policies in the near future. Meanwhile, the present summary statement is offered to all who seek fuller understanding of the nature and dimensions of the complex, interrelated problems which will determine the quality of life for much of mankind.

PHILIP HANDLER
President
National Academy of Sciences

H. GUYFORD STEVER
Director
National Science Foundation

Preface

The problems of maintaining a balance between the world population—now approaching 4 billion—and food supplies have aroused widespread concern.

In 1974 a World Population Conference (Bucharest) declared a need for managing the rate of population increase, and a World Food Conference (Rome) initiated the organization of a food early-warning system, an international food reserve, an international food-aid policy, and a program for stimulating the agricultural productivity of the developing nations. In the past few years, the food-producing system of the world has shown notable irregularities, and there is widespread concern about maintaining a functional balance between population and food. Because of these dynamic changes in the world situation, the present study of critical issues involved in the population/food balance was initiated.

The prospect of an inadequate food supply is not new; the realization that agricultural production must increase in proportion to increases in population is not new; publication of reports analyzing the relations between food and population is not new. But the urgency of forcefully addressing the problems associated with the population/food situation increases with each passing day. The intent of this report is to urge, as strongly as we can, that international attention be given to the problems and that concerted action be taken to alleviate them.

Our main focus here is on world agriculture, because that is the basis of our hope for the immediate future. But we consider that the primary issue for the longer-term future is reduction in the rate of growth of world population and, as soon as possible, attainment of population equilibrium.

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Contents

Introduction

Throughout history, each major inhabited region of the earth has produced its own food supply; agricultural production in each has, in a general way, kept pace with its population growth. International trade in major foodstuffs has represented only a small fraction of global agricultural production, in part because few regions produced substantially more than was sufficient for their own needs. From time to time, the vagaries of climate have resulted in serious agricultural failure, with consequent famine; witness such tragedies as seven consecutive drought years in Biblical times in which the Nile failed to flood the Egyptian plains, and a history of repeated failures of the monsoon rains in India—occasionally for 2 or 3 successive years. In other instances, diseases, insects, wars, political upheavals, and comparable factors have exacted their toll.

As populations grow, crop failures in a given region, from whatever cause, affect ever-greater numbers of people. It has been estimated that the number of people who starved to death in the seventeenth century was probably under 2 million, in the eighteenth perhaps up to 10 million, in the nineteenth perhaps 25 million, and thus far in the twentieth, perhaps 12 million. As the end of the twentieth century approaches, the rising population places severe demands on the stability and the continued rise in productivity of our agricultural system. Failure of world agriculture to keep pace with world population growth, currently about 2 percent per year, or major regional crop failures because of adverse climate could now claim more lives than at any time in the past.

Indeed it is mainly the improved communications and early warnings, the productivity of North American agriculture, and a worldwide food distribution system responsive to regional disaster that offer reason to hope that the next decade need not necessarily witness major famine.

Less dramatic than famine, but in the aggregate more tragic, perhaps, is the degradation of large numbers of human lives by chronic malnutrition. It is difficult to estimate the extent of malnutrition, either in the past or at present. Among the peoples of the Far East, Near East, and Africa today, it has been estimated that malnutrition seriously affects as much as 15–25 percent of the population (FAO, 1973b). The total number of seriously malnourished people in the world today may be as great as 460 million, about 15 percent of the total population of the developing nations in the tropical and subtropical regions.

The dimensions of the problem of adequately feeding mankind were defined, in 1967, in a report of the Panel on the World Food Supply of the President's Science Advisory Committee (PSAC, 1967), which provided a comprehensive evaluation of both the potential food supply and food requirements extrapolated to 1985. Numerous other relevant reports have since appeared, including those of Blakeslee *et al.* (1973), Borgstrom (1973), Brown (1974), Brown and Eckholm (1974a, b), Hare (1974), Mayer (1970), Mesarovic and Pestel (1974), NAE (1970), NAS (1971), Poleman and Freebairn (1973), The Conference Board (1974), United Nations (1971, 1974), and Walters (1973).

The Consultative Group for International Agricultural Research—a consortium of international and national assistance agencies, the World Bank and regional banks, and philanthropic foundations—was formed to support agricultural research and training centers to serve less developed parts of the world. Its continuing Technical Advisory Committee, consisting of 13 internationally known scientists from Africa, Asia, Latin America, North America, and Oceania, has prepared a comprehensive report on international agricultural priorities (FAO, 1973a); in essence, their findings reinforce those of the 1967 report (PSAC, 1967).

The principal concern of this statement is the long-term assurance of a food supply for mankind, a supply adequate not only for preventing starvation but also for abolishing the lingering impact of malnutrition. The principal question is whether world agricultural production can keep pace with population growth and whether the products can be available where they are required. Emphasis here will be placed on the requirements for ensuring agricultural success. The challenge is to keep pace with the increase in our numbers while population expansion is brought under control.

Population

For most of the time since the appearance of *Homo sapiens,* worldwide population growth was much less than 0.1 percent per year. Until World War II, the rate of increase had never been known to exceed 1 percent annually, and the population of rich areas grew as rapidly as, or more rapidly than, that of poor areas. After 1950, there occurred a remarkable acceleration of world population growth. High-income countries (the more developed areas) and low-income countries (the less developed areas) are now contributing to the total growth of world population in different degrees and to the rising demand for food in different ways.

The population of the world is now nearly 4 billion, and is increasing at nearly 2 percent per year—about 200,000 persons per day. Making what appear to be reasonable assumptions, the United Nations demographic office projects a minimum world population in 2000 of 6 billion and a maximum of 7.1 billion (Table 1). The median, about 6.5 billion, may be considered a reasonable basis for comparison with projections of future world food supply. In the developed countries, the rate of increase, now only about 0.8 percent, is declining steadily. In the developing countries, the average rate of increase is about 2.5 percent, a record rate that has just begun to decline on a global basis and may not

TABLE 1 United Nations Alternative Projections of World Population (billions)[a]

Projection	1970	2000	2050	2150
Low	3.6	6.0	9.2	9.8
Medium	3.6	6.5	11.2	12.3
High	3.6	7.1	13.8	16.0

[a] Adapted from Brown (1974).

yet have reached its peak in some countries.* According to the same median estimates provided by the United Nations, 90 percent of the projected increase in world population for the remainder of this century will occur in the developing countries.

ESTIMATES OF POPULATION GROWTH

Population growth is dominated by the current circumstances of Asia, Africa, and Latin America, where 85 percent of all births occur and where 75 percent of the world's people live. The population of southern Asia (India, Pakistan, Bangladesh, and Sri Lanka), with a current combined total of 1.3 billion, is increasing at a rate of 2.4 percent per year—almost 40,000 persons per day. Indonesia, the fifth largest nation, is increasing at 2.6 percent per year. In Africa, where total population was estimated at 374 million in 1973, the growth rate is about 2.6 percent per year; current projections suggest a population of 530 million in 1985 and 818 million in 2000. African birthrates exceed those of any other continent, and growth is held to 2.6 percent by continuing high death rates. The Latin American population, as a whole, is growing at 2.8 percent per year; the rate in Brazil is 2.8 percent and in Mexico 3.2 percent.

Almost of necessity, demographic projections are subject to a large element of uncertainty. However, certain major aspects of future population growth can be foreseen with assurance. The seeds of the future development of a given population are contained in its current demographic situation. In most of the developing countries the high birthrates are decreasing slowly, if at all. Meanwhile, there has been, until recently, a steady decline in death rates, accounting for the steep

*To calculate the time required for a population to double, divide 70 by the growth rate expressed as percent per year—e.g., a population growing at 3.5 percent per year will double in $70 \div 3.5 = 20$ years.

acceleration in the rate of population increase of the developing countries. Indeed, because death rates still remain high in much of tropical Africa and in parts of southern Asia, there is still the possibility of further acceleration in growth. In recent years, to be sure, there has been a steep reduction in the birthrate in such smaller lands as Hong Kong, Singapore, Taiwan, South Korea, Sri Lanka, West Malaysia, Barbados, Chile, Costa Rica, Trinidad and Tobago, Jamaica, Puerto Rico, Mauritius, Egypt, and Tunisia, and a lesser reduction in a few other populations, including, reportedly, that of China. But in the large populations of southern Asia, Africa, and Latin America there are few signs of a decline in fertility.

Substantial population growth continues for a considerable period well after fertility has fallen to a level that would, in the long run, just ensure population replacement—i.e., about two children per couple. Rapid population growth cannot stop abruptly; the changes in customs and behavior required to reduce fertility cannot occur overnight. A perhaps less obvious but even more compelling reason for the persistence of population growth is the very large proportion of younger persons in a population with high fertility. The large fraction of persons under age 20 in such a population implies an inevitable increase in the number of persons of childbearing age in the next generation (Table 2). Even if each couple produces just enough children for replacement, the final size of the population will reflect the very large number of young people today rather than the more moderate number of current adults.

If the more developed areas maintain fertility at or below the replacement level and the developing countries attain that level by the

TABLE 2 Percentage of Population below Age 15 in the 20 Most Populous Nations, 1972[a]

Nation	Percentage	Nation	Percentage
China	36	Nigeria	45
India	42	United Kingdom	24
Soviet Union	29	Italy	24
United States	27	Mexico	48
Indonesia	45	France	25
Japan	24	Philippines	43
Brazil	42	Thailand	46
Bangladesh	45	Turkey	42
Pakistan	44	Egypt	42
West Germany	23	Spain	28

[a]Adapted from Brown (1974).

end of the century, the total population of the world might level off in 70 years at about 8 billion, more than 80 percent of it in the presently "developing" areas.

This projection of a stable world population after the middle of the twenty-first century, twice that of current world population and with intervening growth predominantly in the developing nations, is based on demographic considerations and hoped-for fertility patterns. It assumes a world food supply, at that time, at least double that of the present. However, it seems unlikely that fertility will decline to replacement levels in the next two decades because, worldwide, births per woman average 4.7. Hence, unless other forces intervene, a world population of 10 billion or more is possible, from purely demographic considerations.

In the long run, attainment of an average rate of increase very close to zero is inevitable. Even a misleadingly modest rate of increase, if continued, leads ultimately to impossible total numbers. At 2 percent per year, population increases sevenfold in a century; at 3 percent it increases about nineteenfold in that time. What is uncertain is not whether rapid population increase will continue indefinitely, but what the total population will be when growth does cease, and how equilibrium will then be maintained. Will equilibrium be maintained with a high birthrate and short life span or with a low birthrate and long life span? Which of those conditions represents the long-range prospect for humanity will depend in considerable part on the food supply available when the population levels off.

SLOWING POPULATION GROWTH

The growth of human populations constitutes a continuing threat to the well-being and peace of mankind. After World War II, there began a major effort to assist the less developed nations of the world in increasing their per capita incomes and improving their public health. There have been some noteworthy successes; but, in country after country, the potential benefits of an increased gross national product and total food supply have been offset by population growth (see Table 3). Leaders of those nations who agree to the imperative of reduction in population growth have substantially differing views concerning how the reduction is to be accomplished.

Historically, in the now "developed" nations, population growth spurted when sanitation was introduced, food supplies became relatively assured, and industrialization began. Subsequently, as incomes rose, population growth declined, sometimes ceased, even before the advent of

TABLE 3 National Sources of World Population Increase, 1972

Nation	Increase (millions)[a]	Rate of Increase (%)[b]
China	13.3	1.7
India	12.8	2.4
Indonesia	3.4	2.6
Brazil	2.8	2.8
Soviet Union	2.2	1.0
Bangladesh	1.9	1.7
Mexico	1.8	3.2
Pakistan	1.7	3.1
Japan	1.4	1.3
Nigeria	1.4	2.7
United States	1.3	0.9
Philippines	1.3	3.3
Thailand	1.1	3.3
Iran	1.0	3.0
Turkey	1.0	2.5
Egypt	.7	2.4
Colombia	.7	3.2
Ethiopia	.7	2.4
Burma	.7	2.4
South Korea	.7	2.0
All other countries	19.1	–
TOTAL	71.0	
WORLD AVERAGE		1.9

[a]Data from Brown and Eckholm (1974a).
[b]Data from Population Reference Bureau (1975).

modern contraceptive technology. There are those who argue that the now-developing nations should be expected to follow a similar course, with population growth thereby "taking care of itself."

We are fully agreed concerning the need to assist these nations in their economic development, and we are fully agreed that government-sponsored programs of family planning cannot expect success without concomitant economic development. Family planning is far more welcome when the family has a sense of assurance of employment, at least a modest income, a reasonable food supply, decreased infant and child mortality, and medical care throughout the life span. These, in turn, are unlikely in the absence of education, literacy, and significant change in the status of women.

However, the significant difference between the situation of many of the developing nations today and the situation that the now-developed nations were in one or two centuries ago is that, largely because of reduction of the death rate by public health measures, the former already know populations so large that their nutrition cannot be sustained by classical agriculture on their own lands while these already swollen populations are increasing at historically unprecedented rates. Accordingly, it appears highly desirable that efforts to stimulate development be paralleled by support of family planning in such manner and by such methods as may be deemed appropriate within each nation.

Certainly, for the long term, braking the rapid rise in human populations is the most central, urgent, and imperative measure in moving toward a solution of the population/food problem. One can easily imagine substantially increasing food production only to find that, in the absence of success in reducing population growth, a crisis involving 4 billion persons in 1975 had been exchanged for a crisis involving 7 billion or more in 2000. Meanwhile, increasing the world food supply can serve constructively because it improves the health of present populations and provides additional time in which to achieve the primary goal of slowed population growth.

A reduction in the current high fertility rates in developing countries could have immediate advantages. Such reduction would afford modest relief in the food/population balance by producing a somewhat smaller population increment each year than would otherwise occur. More important, it would improve nutrition in the many poor families in which malnutrition is aggravated by a large number of children and by short interbirth intervals that, through early weaning, deprive children of essential protein. The advantages of reduced fertility become ever greater as a longer time horizon is contemplated. When extended to several decades, reduction of fertility in areas where the birthrate is now high becomes an absolute requirement if there is to be an acceptable balance between population and food supply.

In a number of developing countries where a sharp decline in fertility has recently occurred, an important contributing factor appears to have been government support of family-planning programs. There are official policies to reduce the rate of population growth in an increasing number of developing countries, including some with the largest populations, such as China and India. Nevertheless, population growth is proceeding at startling rates in many other parts of the world, most dramatically perhaps in such developing nations as Mexico, Algeria, Ecuador, and Venezuela.

Admittedly, there are governments that have thoughtfully concluded that the populations of their countries are insufficient to allow satisfactory economic development of their lands. Where this is not the case, however, it is to be hoped that governments will find it desirable to support vigorous family-planning programs, making information and materials available to the most remote citizen, while pursuing efforts that, by improving economic status, will change national mores so that large families no longer seem desirable. In most countries today, economic development and population policy are complementary in that they require the same set of public policies with respect to food distribution, land use, education, medical care, old-age insurance, employment opportunities, tax incentives, and changes in the status of women. The sooner economic development can be achieved, the sooner population growth will decelerate.

The governments of developed nations that do not have to contend with burdensome population growth have a considerable stake in the outcome everywhere else; no nation can long be immune to the consequences of unbridled population growth elsewhere. Since it is unlikely that the developing nations now hard pressed by rising costs of energy can finance these programs by themselves, it is in the self-interest of the developed and affluent nations to assist in this effort. There is no humane alternative.

Food and Health

In many developing countries, large numbers of the children are malnourished. The immediate consequences are high mortality rates for infants and preschool children. When the deficiency is early, prolonged, and severe, there is a lasting effect on mental development and learning capacity. At times of actual famine, young children, along with expectant and nursing mothers, are the first to suffer, which leads to yet greater child mortality and often further impairment of the physical and mental development of the survivors. Moreover, this very situation engenders a perceived need for more children, so as to ensure the survival of some desired number, with consequent resistance to family-planning measures.

The marginal nutritional state of adults is exacerbated by the fact that hookworm, malaria, schistosomiasis, and other parasitic diseases contribute to the occurrence of malnutrition by interfering with the absorption of nutrients and even by causing extra losses of key nutrients from the body. Moreover, the high frequency of gastrointestinal, respiratory, and other infectious diseases, especially in young children, further exacerbates the impact of malnutrition through direct and indirect effects on food intake and metabolism. The synergism of parasitic or infectious diseases with malnutrition is thus responsible not only for increased morbidity and mortality but also for less efficient use of such food supplies as are available. Persons who carry a heavy burden of disease have a greater need for protein and certain other essential nutrients than do those not thus afflicted.

The consequence is a population that may be quite unable, on its own effort, to break out of its circumstances. The combination of chronic malnutrition and infectious disease is enfeebling, both physically and mentally. Only intervention can protect the next generation and give them the opportunity to explore their full human potential.

Intervention, in the developing countries, must take the form of publicity, usually governmentally sponsored, aimed at the several facets of these intertwined problems. Programs of preventive immunization and improved sanitation and various measures for disease control also improve the ability of the population to survive on otherwise nutritionally marginal diets. Conversely, effective improvement in nutritional status will tend to lessen the severity of the infectious and parasitic diseases. Meanwhile, it must be remarked that the means for control of many tropical diseases are less than satisfactory and warrant a major research effort.

There can be no better investment in the future of some countries than a system of clinics or their equivalent, to ensure the care of infants and pregnant and nursing women, plus a program to ensure the nutrition of preschool children. This can frequently be done with indigenous foods, provided they are carefully selected for nutritional balance. When required, assistance to such programs is a particularly worthy form of food aid.

THE FOOD SUPPLY

The sustenance of human life depends on the agricultural production of a few crops, the most important of which are wheat, rice, corn, soybeans, millet, and the grain sorghums. Other pulses, fruits, fish, green vegetables, nuts, and meat all make significant contributions, particularly to the state of individual health, but the primary source of calories and of protein for man consists of cereal grains and, to a lesser degree, certain legumes. The great growth of world population in this century has been made possible by a concomitant increase in the production of these basic crops. Production now totals about 1.2 billion tons per year.

The agricultural enterprise has become increasingly sophisticated and scientific. The yield for all grains averaged about 1.15 metric tons/hectare* in 1934–1938, at which time it was about as high in the developed as in the presently developing nations. By 1970, average yield had increased to 2.2 metric tons per hectare in the developed nations but to

*One hectare = 2.47 acres.

only 1.41 metric tons per hectare in the developing nations. This growth in productivity in the developed nations resulted from a combination of genetic breeding of disease-resistant, high-yielding seed stocks adapted to specific regional climatic and soil conditions; application of fertilizer; irrigation; the use of pesticides and herbicides; and the mechanization of major farm operations. These practices, which require an extensive "agribusiness," an agricultural research establishment, sophisticated advice to farmers, available capitalization and credit, an adequate transportation system, and a market economy, were much more easily adopted in the already industrialized world than in the less developed nations. Corn yield has increased more dramatically than the yield of any other crop. In the United States, 60 million acres were in corn in 1970. If the agricultural practices followed in 1945 had been followed in 1970, growers would have had to plant 140 million acres in corn in order to achieve the 1970 production. Worldwide wheat yields per hectare increased about 25 percent per decade from 1950 to 1970, those for rice increased about 22 percent in 1950–1960 and 15 percent in the next decade, and those for corn increased 30 percent in the first decade and 25 percent in the second. These are about 3, 3, and 2 times as great as the world averages. Although rice is a minor American crop, yields are 5.1 metric tons per hectare, compared with 2.3 in Asia, where most of the world's rice is grown. The present concern over the ability of the world's agriculture to provide adequate food for the developing nations results (1) from the low agricultural productivity of those nations (compared with the productivity of the developed nations) and (2) from the increases in the already large populations of those nations.

In some developing nations, the average person is sustained by the equivalent of about 400 lb of the locally indigenous cereals per year—just over 1 lb per day, which is barely sufficient to support life. Nearly all of this is eaten directly; little can be spared for conversion to meat, milk, and eggs. In these nations, overall demand for cereals can be expected to increase at a rate no less than the rate of population growth, or 2.5 percent per year, if present inadequate nutritional levels are maintained. Since the distribution of income in these nations, as in others, is highly unequal, there are many, perhaps 20 percent of the population, whose consumption is significantly below the national average. Their diets are often insufficient not only in protein and vitamin content but also in calories. Per capita incomes in developing nations have been rising at the rate of 2 percent per year. In these populations, where as much as three fourths of personal income is spent on food, increased income results in a demand for more and better food. Hence, national demand for food has been growing more rapidly than has population—i.e., about 3 percent per year—but in many of these nations food production has not been keeping pace. Much of the population is still restricted to diets of only the available basic grains, and many do not receive enough to sustain life.

Unfortunately, despite their significance in human nutrition, few cereal grains are nutritionally adequate, in themselves, for man. Virtually all are unbalanced amino acid mixtures, deficient in one or another of the nutritionally essential amino acids. This can be remedied by ingestion of appropriate mixtures of cereals and by supplementation with legumes, fruits, vegetables, and nuts, as well as by modest amounts of milk, eggs, meat, or fish. The populations that lack opportunities for such dietary enrichment are the ones that exhibit signs of protein and vitamin deficiency.

The Food Supply for the Near Term

Although the actual magnitude of the food problem is not known, many reports indicate famine in various developing nations, and death rates are reported rising in at least 12 and perhaps 20 nations, largely in central Africa and southern Asia. As we have noted, over any prolonged period, food production must keep pace with population—i.e., an increase of at least 2 percent per year, worldwide, and more in faster-growing countries. But, from year to year, gains in food production may be less than 2 percent. Setbacks are caused by adverse climate, insects, disease, the supply of fertilizer, war, and so on. A setback occurred in the United States in 1972 when heavy rains and subsequent drought as well as the Southern corn blight markedly reduced production of each major crop. These reductions coincided with major crop failures elsewhere. In 1974–1975, the total world grain production declined from 1,177.8 to 1,132.9 million metric tons, a decline of almost 45 million tons. This included a decline of 15.9 million tons in wheat and a decline of 28.1 million tons in course grains.

The most serious problem arises in already hard-pressed southern Asia, where the edible grain crop was estimated at about 8 million tons less than it was in 1973–1974. (These estimates coincide with reports of famine in India and Bangladesh.) The poor crop of the winter of 1974–1975 followed a 2-year period when edible grain reserves of the world were drawn down to one third of the level of 1971–1972. World wheat, rice, and coarse grain stocks were 14, 3, and 9 percent, respectively, of annual consumption; only about one third of these stocks is held by major exporters and, hence, would be reasonably available for emergency shipment (see Table 4). Nevertheless, total worldwide

TABLE 4 Grains Available for Export by Major Exporters, 1974–1975[a]

Exporter	Grains and Amounts (thousands of metric tons)[b,c]		
	Wheat	Rice	Coarse Grains
United States	25,850	2,130	24,255
Canada	12,600	–	3,000
Australia and New Zealand	7,600	–	2,500
Argentina	3,000	–	8,700
China	–	1,300	–
South Africa	–	–	3,700

[a]Data from USDA (1974).
[b]World total available for export (thousands of metric tons): Wheat, 53,000; rice, 4,700; coarse grains, 46,200.
[c]World production (thousands of metric tons): Wheat, 350,000; rice, 210,000; coarse grains, 572,000.

production of these foodstuffs would suffice to meet basic world nutritional requirements if appropriate distribution could somehow be arranged.

Whether that can be done depends in part on the way in which the few countries that produce significantly more than they consume, notably the United States, use their surplus (Table 4). Not only is the United States the chief exporter of wheat, rice, and coarse grains (Table 4), it is also the chief exporter of soybeans (about 80 percent of world trade), edible oil (33 percent), and oilseed meal and fishmeal (58 percent). American exports in the last few years have come from a mixture of annual production and reserves. The reserves accumulated as a result of the government's program of price supports to protect the farmer. Total American agricultural exports rose from 55 million tons in 1970 to 92 million in 1973 and to 100 million in 1974. By fall of 1974, accumulated reserves were seriously drawn down to the point where exports must derive largely from annual production, and the relatively poor 1974 soybean, wheat, and corn crops necessitated a significant reduction in exports from the previous year, when the United States exported 63 percent of its wheat, 50 percent of its rice, 44 percent of its soybeans, 24 percent of its grain sorghum, and 23 percent of its corn. Of the 31.2 million tons of wheat shipped in 1973–1974, 16.1 million were shipped to developing nations and 7.5 million to developed nations; the remainder went to developing nations in concessional sales or direct food aid. That pattern did not hold for other agricultural products, however; two thirds of the total agricultural sales ($21.3 billion) were sales to developed nations. (In this connection, see Figure 1 and Table 5.)

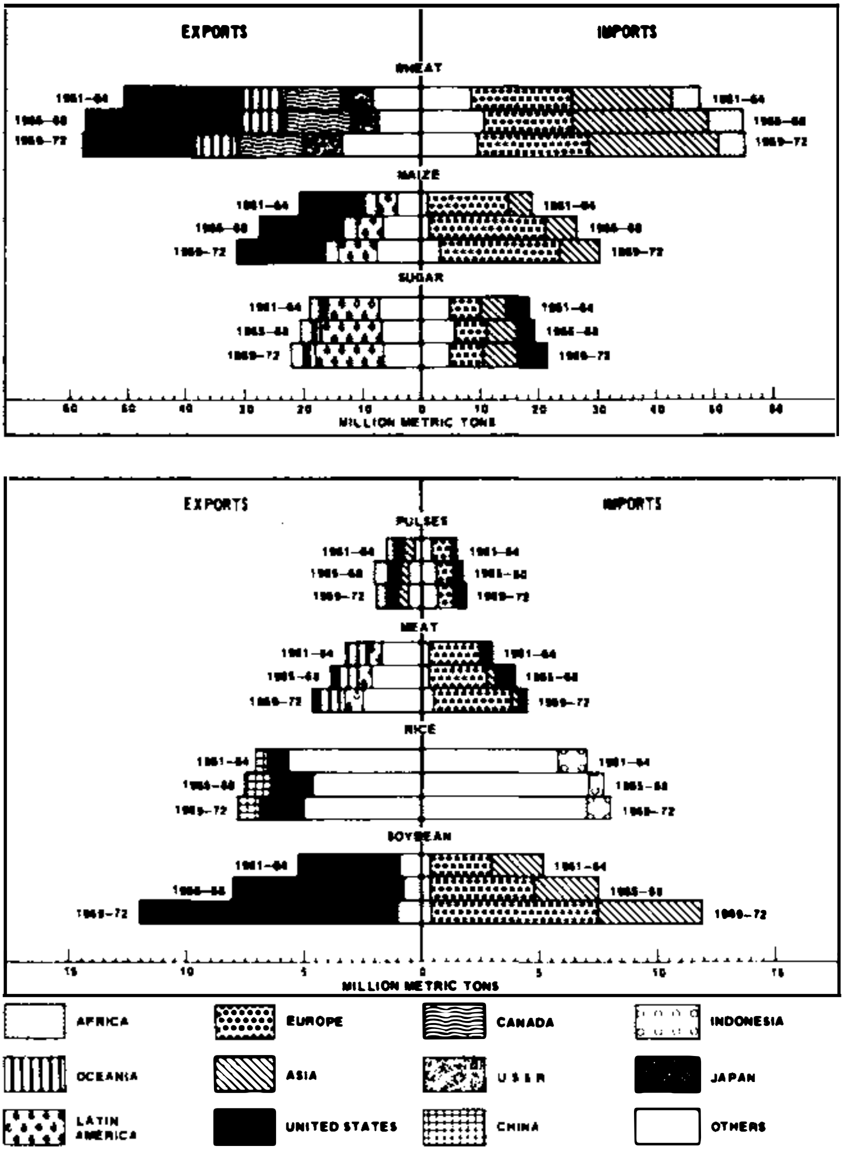

FIGURE 1 World exports and imports of seven food commodities, 1961–1972. (Reprinted with permission from University of California Task Force, 1974.)

TABLE 5 The Changing Pattern of World Grain Trade[a] (Data in millions of metric tons. Plus = net exports; minus = net imports.)

Region	1934–1938	1948–1952	1960	1966	1973[b]
North America	+5	+23	+39	+59	+91
Latin America	+9	+1	0	+5	–3
Western Europe	–24	–22	–25	–27	–19
Eastern Europe and Soviet Union	+5	–	0	–4	–27
Africa	+1	0	–2	–7	–5
Asia	+2	–6	–17	–34	–43
Australia and New Zealand	+3	+3	+6	+8	+6

[a]Adapted from Brown and Eckholm (1974a).
[b]Preliminary, fiscal year.

The food deficit of the developing nations of southern Asia has been occasioned by bad weather, lack of fertilizer, lack of fuel for irrigation pumps, and a serious drain on monetary reserves. The drain on monetary reserves has been aggravated by war and the rise in oil prices. It is not clear to what extent the financial drain imposed by rising oil prices will depress imports of agricultural products by the developed, already reasonably well-fed nations or change the availability of agricultural products to the developing nations.

The Food Supply for the Longer Term

Estimates of future world food production seldom venture beyond the next decade. A University of California food task force has extended to 1985 previous projections by the Food and Agriculture Organization, largely by extending trend lines (Table 6). They have, similarly, projected world market demand and used United Nations estimates of median population growth. By this analysis, worldwide supply and demand in 1985 will be in close balance, as at present. But the peoples of Asia, Africa, and Latin America are seen to confront a shortfall of 11 percent of cereal grain requirements, as compared with 8 percent in 1970. This 100 million tons of grain would cost $150 per ton, or $15 billion. Europe, as today, is seen obtaining a large amount of its food from elsewhere. This reflects basic grain requirements less than it does the requirements for feed grain for poultry and livestock. The ability of Europe and Japan to command the exchange necessary will depend on the stability of their economies and on their success in meeting the financial costs of energy.

TABLE 6 Projected Production of Major Crops, Worldwide (millions of metric tons)[a]

Crop	1970	1985
Wheat	333	460
Rice	308	444
Corn	278	421
Soybeans	57	69
Sugarcane	589	852
Potatoes	298	431
Dry beans	11	16

[a]Data from University of California Task Force (1974).

The validity of this projection cannot be determined. But it depicts a world in which, as in today's world, agricultural effort barely keeps pace with demand.

In an effort to look beyond the next decade, Mesarovic and Pestel (1974) divided the world into 10 regions and examined their futures up to the year 2025, using an elaborate rate-systems analysis. By their analysis, in all but one region, indigenous food supplies will more or less keep pace with population growth. But their projection of the future of southern Asia is bleak. They indicate that if present trends continue, that region will contain 3.9 billion people in 2025—a number equal to the present total world population. The food supply at that time simply will not permit such an expansion in one region. Another assumption is that population control measures in the region will begin to take hold by about 1990–1995 and that child deaths will increase significantly. This is found to lead to a population of 2.9 billion in 2025. When these authors make what appear to them to be reasonable assumptions, they conclude that the food deficit in that part of the world will considerably exceed the North American food "surplus" in 2000 and the whole of North American production in 2025.

The validity of these projections is here neither supported nor challenged. Rather, we direct attention to their existence and to the urgent implications for national and international policy.

PROTEIN SUPPLIES

A central issue of the world food situation is the supply of protein of nutritionally appropriate composition. It is estimated that 75 percent of the protein consumed by man comes from such plant products as grains, legumes, and root crops (Borgstrom, 1973). The remainder is consumed as meat, fish, and animal products. Lack of sufficient suitable protein is one of the chief nutritional deficiencies in the world. Protein–calorie malnutrition affects a large proportion of young children in developing countries, and kwashiorkor, caused by a deficiency of protein relative to calories, is a major cause of death in many developing countries.

Protein production faces constraints from the necessarily limited supplies of meats, legume crops, and fish. World production of beef is limited by diseases, especially trypanosomiasis and foot-and-mouth disease, and its efficiency is held down by the fact that it has not been possible to devise a feasible means of producing more than one calf per cow per year. For every animal that goes into the beef production process, one additional adult must be maintained for a full year. Furthermore, the grazing capacity of much of the world's pastureland—e.g., most of the United States Great Plains area, east Africa, and parts of Australia—could be expanded only at substantial cost. Large-scale poultry "factories" are difficult to manage in hot, humid climates because the birds become subject to a variety of diseases.

Another constraint on world protein production is the failure to achieve a significant per-acre increase in soybean yields. In the United States, which now produces two thirds of all soybeans entering the world market, yields per acre have increased by only about 1 percent per year since 1950; maize yields, in contrast, have increased by nearly 4 percent per year. In consequence, at current prices, on land that yields 100 bushels of corn but only 28 bushels of soybeans per acre, it can be more profitable for the farmer to plant corn than soybeans. One reason that soybean yields have not climbed very rapidly is that legumes, which themselves engage in nitrogen fixation, are not significantly responsive to nitrogen fertilizer.

Soybeans are a major source of high-quality protein for swine and poultry in much of the world and are consumed directly as food by more than a billion people throughout densely populated eastern Asia. The practice of using soybean meal, which is 50 percent protein and contains a reasonably well-balanced mixture of amino acids, as a "meat extender," will surely increase consumption of soybeans in the United States and elsewhere. Meanwhile, only about 3 percent of soybeans consumed in the United States are eaten by humans; the bulk is fed to livestock and poultry.

World demand for soybeans is increasing rapidly, and prices are rising correspondingly. Accordingly, American exports in fiscal year 1974 totaled $3.27 billion. This amount was surpassed by only two agricultural products: wheat ($4.74 billion) and feed grains ($4.65 billion), and it surpassed the export sales volume of such products of "high technology" as jet aircraft and computers. In view of the nutritive value of this legume, it seems highly desirable that world plantings be expanded wherever possible. It is gratifying to note a 10,000-hectare planting in France for the first time and the emergence of soybeans as a major export crop in Brazil.

There has been a worldwide drop in the per capita production of such other legumes as the common bean, chick pea, mung bean, and broad bean, with a subsequent rise in their prices and decreased consumption of legumes by those peoples who most need them to complement predominantly cereal diets. Urgent attention needs to be given to increasing world legume production to a point at least comparable with the population increase.

MARINE FOOD SOURCES

The importance of fish in the human diet has risen steadily over the past generation, as man's capacity to harvest the oceans has improved. By 1971 the world fish catch approached 70 million metric tons, of which 64 percent was table grade—an average of about 40 lb per person. This may be compared with world beef production of 35 million metric tons and with world grain production of 1,200 million metric tons. The rest of the catch, which includes the large Peruvian anchovita fishery, is used as a high-protein supplement for animal feeds and as fertilizer. Nearly 90 percent of the world fish catch comes from oceanic fisheries.

After World War II, investment in fishing capability multiplied severalfold, and there was a rapid expansion in world fishing fleets. The technology of fishing became increasingly sophisticated and included the use of techniques such as sonar to locate fish. Between 1950 and 1968, the world fish catch increased by nearly 5 percent each year, rising from 21 million to 63 million metric tons. After a small drop in 1969, it rose sharply to 70 million tons in 1970, then fell for the next three years (Table 7) to about 66 million tons. Much of that decline resulted from the disappearance of the anchovita from the Peruvian coast. These have begun to reappear. In future years that fishery will probably sustain a large catch, although somewhat smaller than the maxima of the 1960's. It appears that other fisheries have been overharvested (e.g., halibut and haddock), and many marine biologists feel that the global catch of table-grade fish may have reached or even passed its maximum sustainable limit.

TABLE 7 World Fish Catch: Total and per Capita[a]

Year	Total Catch (million metric tons)	Per Capita (kilograms)
1950	21	8
1951	24	10
1952	25	10
1953	25	10
1954	28	10
1955	29	11
1956	30	11
1957	32	11
1958	33	12
1959	36	13
1960	40	14
1961	43	14
1962	46	15
1963	48	15
1964	52	16
1965	52	16
1966	57	17
1967	60	18
1968	63	18
1969	63	18
1970	70	19
1971	69	19
1972	66	17
1973	66	17
1974 (preliminary)	69–70	18

[a]Adapted from Brown (1974); data for 1972–1974 from FAO.

Biological knowledge of the limits of marine production is inadequate. Overfishing is usually recognized only when the catch begins to decline. The situation is seriously aggravated by the competition among nations for this limited resource. There is, therefore, an acute need for studies that will establish the size of the annual catch sustainable by each major fishery and for international agreement concerning the allocation of these resources.

Agricultural Resources

LAND

Until about the middle of the twentieth century, frontiers existed where new lands could readily be put to agricultural use. Few such frontiers exist today; most of the readily utilizable arable land of the world is under cultivation. In 1970, 3.19 billion hectares were in use around the world; of this, about 150 million hectares were in the United States.

Some parts of the world actually face a net reduction in agricultural land because of pressure from competing uses— industrial, recreational, transportation, and residential—and because of limited opportunity to open new lands. Few countries have well-defined policies for protecting agricultural land from other uses. In the United States, much farmland has been diverted to other purposes. Certain of the more densely populated countries—for example, Japan and several Western European countries—have used ever-decreasing amounts of land for crop production in the past few decades. In most parts of the world, including the Indian subcontinent, the Middle East, North and sub-Saharan Africa, the Caribbean countries, Central America, the Andean countries, and the United States, significant amounts of land are lost through erosion each year.

These considerations should not be construed as indicating that the planet has achieved its maximum nutritional carrying capacity for human beings. It is more accurate to say that worldwide agriculture by traditional methods is approaching a maximum.

Potentially, land under cultivation might be doubled, provided there were significant engineering and energy inputs. The vast land areas of the tropics are surely underused despite the attractive possibilities for double- and triple-cropping. It may eventually be possible to farm the hot, humid tropics effectively, particularly if means can be found to manage lateritic soils more successfully; to accomplish this will take much research, time, effort, and money. Similarly, a huge area of high agricultural potential in south-central Africa—7 million square kilometers, according to the Preparatory Committee for the World Food Conference—is infested by the tsetse fly. Control of this insect is a great challenge; it would reduce serious illness while opening an area comparable to the plains of North America. Much arid land in several countries, including the United States and the Soviet Union, could be cultivated if there were adequate supplies of water, but the engineering inputs and energy costs would be vast, and economic motivation is necessary.

However, the chief opportunity to increase food production significantly is offered by the immense areas already under cultivation in the developing countries, where yields are markedly lower than in the United States, Japan, or Europe. Almost two thirds of the earth's population lives between 30° N and 30° S and about half of the domestic animals are here; but this region produces no more than a third of the total agricultural output. These low yields are not necessarily a reflection on the fertility of the soils and certainly do not reflect on the efficiency of the farmers, who are doing very well, given their circumstances. The missing elements are the scientific and technological inputs that characterize high-productivity agriculture.

WATER

The availability of water is critical not only for agriculture but also for industrial and home use. In the twentieth century, the total "withdrawal" of water for all uses in the United States has been doubling at about 20-year intervals. About 370 billion gallons per day are used currently, of which about 35 percent is for irrigation. Projected needs are for twice this amount well before the year 2000 (National Water Commission, 1973). Since the water tables in several parts of the country are already receding at an alarming rate, and without prospect of their regeneration, it is not clear that this projection can be realized.

There are about 200 million hectares of irrigated land around the globe. Irrigated land has been increasing at about 4.5 million hectares per year. If irrigated land per capita is a meaningful parameter, the growth rate approximates population growth at this time. However, if global productivity is to increase, the rate is insufficient.

In many parts of the world, additional productive agricultural land could become available if adequate water for irrigation could be found. At present, less than 4 percent of the total world riverflow is diverted for irrigation. Utilization of most of the remainder is limited by the geographic distribution of river systems whose water can be made available only by formidable engineering projects.

FERTILIZERS

The high productivity of modern agriculture depends substantially on the application of the major plant nutrients: nitrogen, phosphorus, and potassium. Applications of manure have been largely displaced by chemical fertilizers, the use of which increased fivefold during the period 1950–1970, and the rate of use around the world is expected to continue to rise at a compound annual rate of 5.5 percent during the rest of the 1970's. The use of fertilizers by various countries is generally matched by their ability to produce them, as shown in Table 8. Use is heaviest where the original mineral rock is available, or in the case of nitrogen fertilizer, where fuel or energy is available for synthesizing it from atmospheric nitrogen. Only a few nations produce enough nitrogen to allow extensive exports.

Nitrogen fertilizers (e.g., guano, nitrate, liquid ammonia, and urea) have found increasing use. It is estimated that about one third of the grain yield in the United States is attributable to this practice (Council for Agricultural Science and Technology, 1974). After the marked increases in yield in the United States had been observed, the world market for nitrogen fertilizers began to grow rapidly, and world production, still growing, is unable to satisfy world demand. As seen in Table 8, world production in 1974–1975 is expected to total about 36 million metric tons. Consumption is limited by production capacity and by lack of exchange in the developing nations.

Of the three key elements, nitrogen is required in the largest quantities by crop plants, and the availability of nitrogen limits productivity of crops more frequently than does any other nutrient factor. In the United States, where an estimated total of 19 million tons of nitrogen is physiologically required by crop plants annually, about 8 million tons are provided by application of fertilizers; the remainder comes from biological fixation of nitrogen from the air.

World production capability for nitrogen fertilizer, as ammonia, was greatly expanded in the mid-1960's, and prices fell to around $20 per ton.

TABLE 8 Expected Fertilizer Production and Consumption in Several Countries, 1974–1975 (thousands of metric tons)[a]

	Nitrogen			Phosphate			Potash		
Country	Production	Consumption	Balance	Production	Consumption	Balance	Production	Consumption	Balance
Developed Countries									
United States	9,616	9,616	0	6,695	5,445	+1,250	2,676	5,096	−2,420
Soviet Union	7,500	6,500	+1,000	3,700	3,400	+ 300	7,100	4,600	+2,500
Japan	2,120	840	+1,280	730	730	0	0	630	− 630
France	1,750	1,823	− 73	1,730	2.230	− 500	2,170	1,940	+ 230
West Germany	1,600	1,250	+ 350	950	900	+ 50	2,400	1,250	+1,150
Netherlands	1,550	410	+1,140	370	100	+ 270	5	124	− 119
Italy	1,180	740	+ 440	470	550	− 80	230	260	− 30
Canada	830	525	+ 300	750	550	+ 200	6,200	220	+5,980
Spain	818	780	+ 40	560	500	+ 60	540	270	+ 270
United Kingdom	705	710	0	465	470	− 5	0	430	− 430
Belgium	625	160	+ 465	750	147	+ 600	0	185	− 185
Norway	530	80	+ 450	120	58	+ 62	0	63	− 63
Developing Countries									
China	3,100	4,600	−1,500	800	1,250	− 450	85	235	− 150
India	1,300	2,100	− 800	376	590	− 214	0	380	− 380
South Korea	568	506	+ 60	218	284	− 66	67	223	− 156
Mexico	500	783	− 280	375	240	+ 135	0	40	− 40
Pakistan	300	450	− 150	10	105	− 95	0	3	− 3
Indonesia	256	441	− 185	0	105	− 105	0	46	− 46
Taiwan	240	200	+ 40	62	52	+ 10	0	72	− 72
Bangladesh	160	145	+ 15	19	54	− 35	0	16	− 16
Brazil	175	475	− 300	350	830	− 480	0	525	− 525
Turkey	160	490	− 330	170	320	− 150	0	14	− 14
Egypt	130	420	− 290	85	60	+ 25	0	3	− 3
Philippines	75	172	− 97	43	57	− 14	0	70	− 70
TOTAL	35,995	34,420		20,757	19,957		21,473	16,792	

[a] Data from USDA (1974).

As a consequence, inventories rose and many small production units were closed down. Exports brought the market into balance in 1969. Thereafter, as both domestic and foreign demands rose, prices climbed to unprecedented highs of over $300 per ton. In 1973, U.S. exports dropped to one third of their 1969 level, in part because of increased domestic demand, and by early 1975 the United States imported some nitrogen fertilizers, chiefly urea. Because of limited supplies of natural gas and, perhaps, because of limited capital for construction, little expansion of American capability for production of this commodity is expected in the near future; both domestic and foreign sources will be very restricted in 1975 and for some years to come. Moreover, fertilizer shortages in other developed countries have caused marked reduction in fertilizer exports; for example, in May 1974 the Japanese petrochemical industry announced a 15–20 percent cut in fertilizer exports to the rest of Asia.

Reserves of potash and phosphate are large but unevenly distributed in various parts of the world. North America seems to have good reserves of both, but South America has little thus far proven. North and West Africa have very large reserves of phosphate, and exports from Morocco will soon be a substantial fraction of the world market. However, Africa as a whole is lacking in known reserves of potash, and Asia seems to have poor reserves of potash and phosphate.

The dependence of the developing nations on imports for the bulk of their fertilizer is clearly revealed in Table 8. Thus, for many reasons—e.g., education of the farmers, lack of production and transportation facilities, lack of individual credit, and lack of foreign currency with which to import fertilizers—fertilizer use in the developing nations is only a small fraction of that in the developed world. In the developing countries, application of mixed fertilizer (nitrogen, phosphorus, and potassium) was about 14.5 kg per hectare, compared with an average of 77 kg per hectare in the developed world. Moreover, as the table shows, even this average is heavily weighted by the data for China, whose food supply is not known to be seriously inadequate. This circumstance illustrates the point, made earlier, that the greatest immediate opportunity to increase food production, worldwide, is to upgrade agricultural practice on lands now in cultivation.

The world market for fertilizers suffers from rapid increases in costs, especially costs for nitrogen. This has particularly troublesome implications for countries that depend heavily on imports for their fertilizer supply, as is the case for India, Indonesia, and the Philippines. The limitations on the supplies of fertilizers available for world trade, at a time when developing countries are becoming increasingly dependent on fertilizer applications for achieving the high yields attainable with the new genetic lines of maize, rice, and wheat, will certainly limit and perhaps reduce food production. During the decade 1963–1973, fertilizer use in developing countries rose 13.9 percent annually (UN data), but the present price and supply situation will cause a substantial drop.

The greatest opportunity for expansion of the world supply of nitrogen fertilizer is in those oil-producing nations where natural gas is still being flared. It has been stated that the gas being flared in the Middle East exceeds all the gas and petroleum used for ammonia synthesis in the United States. Since those nations are accumulating vast capital reserves, they have the means to finance the construction of the necessary production facilities.

American production of potash and phosphate fertilizer is being slowed in response to environmental concerns. These concerns can be met—as they are being met in developing the new phosphate deposits in eastern North Carolina—but at some increase in price. More important, it must be recognized that phosphate rock is a nonrenewable resource and that what may seem to be immense reserves compared with current use may appear less secure on a longer time scale; total American reserves have been estimated to be about 2,464 million tons. American policy with respect to both domestic use and exports should rest on a comprehensive appraisal of the actual magnitude of such reserves.

In the long term, phosphate is likely to be the fertilizer in limiting supply. However, large quantities of phosphate now flowing through municipal sewer systems could be recovered by "tertiary treatment." By appropriate processing (recycling), this could significantly extend the fertilizer supply and at the same time improve the quality of water entering rivers and streams.

PESTICIDES

The losses to agriculture caused by weeds, insects, and diseases can be assessed only approximately but are surely substantial. According to the Food and Agriculture Organization, losses in the field are as great as one fourth to one third of the total. It is estimated that about 12 percent of this loss is due to insects, 12 percent to plant diseases, and the rest to weeds. These problems become more difficult when fields of genetically identical plants are grown. Such fields are vulnerable to attack by pests or spread of diseases; they are particularly vulnerable to an attack by new or unexpected pest species. As developing countries introduce the practices of modern agriculture—fertilization, irrigation, intensified tillage, multiple cropping, and denser plant populations—it is imperative that they also give proper attention to crop protection. In addition to increasing yields, applications of pesticides (insecticides and herbicides) provide considerable benefits in optimal timing and replacement of hand labor. In the United States, roughly 1.2 billion pounds of pesticides were manufactured in 1972.

Crop yields in the developing countries could be increased appreciably if insecticides and herbicides were used more widely. Their use is thought to be increasing at about 11 percent per year in the developing countries, with greatest emphasis on herbicides. As in the case of fertilizers, however, rising costs and regulatory measures will impose restrictions on the extent to which pesticides will be used in the developing countries.

Alternatives to chemical pesticides include breeding programs to increase resistance to diseases and insects and the use of biological control methods. In any region, these alternatives must be preceded by a relatively long period of research and development. They are an essential part of long-term efforts to improve productivity, but they cannot bring about appreciable short-term improvement.

No less desirable is the development of more effective procedures for storing harvested food. Losses in stored foods are caused by insects, rodents, and microorganisms. It has been estimated that, worldwide, the amount of food lost in storage annually is a serious drain on potential supplies, ranging from 5–7.5 percent for grains to near total destruction in certain more perishable commodities (University of California Task Force, 1974). Research addressed to this problem, if successful, would constitute an enormous boon to mankind. Until a remedy is found, prolonged storage of large food reserves will be a hazardous procedure, subject to intolerable losses, in some areas as great as 50 percent per year.

Attention to more efficient technologies of harvesting, transportation, processing, and marketing could also result in considerable increase in food supplies.

ENERGY

Agriculture, in its most productive forms in the developed nations, has been built by substituting mechanical and chemical innovations for hand labor and by capitalizing on the gains in productivity that are associated with large-scale crop culture. It is calculated that the energy invested in the food system in the United States at the farm level doubled between 1947 and 1970 (Pimentel *et al.*, 1973; Steinhart and Steinhart, 1974). Nearly half of this energy input consists of fuel and fertilizer, about one tenth is for pesticides, about one fifteenth is for irrigation, and a substantial fraction represents the requirements for manufacture of farm machinery. During the same period, the proportion of the population involved in farming declined by more than half, and yields per acre more than doubled. In short, energy inputs, particularly in the form of fuel, have vastly lowered the manpower requirement for farming and at the same time have been associated with large gains in productivity (see Figure 2).

In certain cases, the energy investment can become very great in proportion to the energy value of the crop. For example, in irrigated agriculture in the United States, the fossil fuel inputs can be equivalent to 50–70 percent (5–8 million kilocalories per hectare) of the energy contained in the harvested crop. This statement appears less disturbing if one compares energy investment with the potential energy of the entire mature plant rather than with the edible portion alone; in theory, some of the energy could be recovered from the remainder of the plant by suitable means (e.g., large-scale fermentation of cornstalks, wheat chaff,

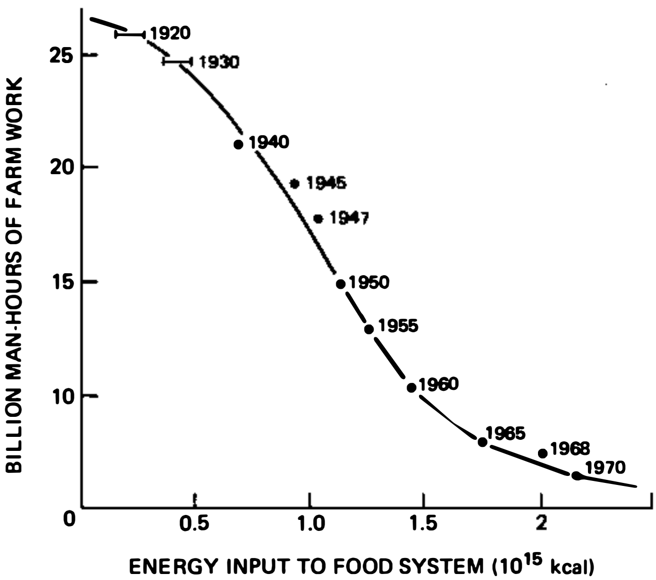

FIGURE 2 Labor use on farms as a function of energy use in the food system, 1920–1970. (From *Energy: Sources, Use, and Role in Human Affairs* by Carol E. Steinhart and John S. Steinhart. ©1974 by Wadsworth Publishing Company, Inc., Belmont, California. Reprinted by permission of the publisher, Duxbury Press.)

and the like) and used to produce methane, methanol, or butanol, if there were sufficient economic incentive.

If the analysis of energy input is extended to include food processing and the commercial and home food-handling sectors, one finds that the energy inputs for each of these categories substantially surpass those for farm production (Steinhart and Steinhart, 1974). In the United States, investment of energy in the farming operation (including manufacture of farm machinery, chemicals, and so on) is about one third of the energy invested in the total food system, which constitutes 12–15 percent of national energy use.

As petroleum sources diminish, the problem of energy invested in the entire food-producing and food-processing system will demand careful scrutiny (Pimentel *et al.*, 1973). Application of the energy-intensive practices of American agriculture in their entirety to developing countries that have restricted supplies of fuels is obviously unwarranted. As a consequence of the dramatic rise in the price of petroleum in 1973, many developing countries find themselves in serious difficulty with respect to fuel supplies. Those developing countries that are oil exporters, such as Iran, Venezuela, Indonesia, and Nigeria, benefit from the current fuel price situation. Those that are self-sufficient in oil, such as Colombia and perhaps China, are relatively unaffected. But about 40 developing countries with little or no oil resources are in serious trouble, including India, Pakistan, Bangladesh, and many countries of sub-Saharan Africa. These are also the countries that must rely on imported fertilizer and pesticides, whose prices have risen sharply in consequence of the higher price of energy.

It seems reasonable to expect that agricultural productivity in developing countries can be effectively increased through the prudent use of fertilizers, pesticides, and irrigation without extensive commitment to mechanization. This more labor-intensive form of agriculture also has the virtue of creating employment in rural areas, which lessens the great burden of urbanization in many developing countries. It seems equally clear that in developed countries there must also be serious attention to economies in consumption of fuel.

TECHNOLOGY

Modern agriculture is a highly technological enterprise, the product of a century of research, with the unusual property that it is highly location-specific. Unlike most engineering technology, that of agriculture must be tailored—for optimum productivity and profitability—to the specific conditions of individual farms or farming areas, with their unique combinations of soil factors, moisture, day length, temperature, complexes of strains of disease organisms and insect pests, and local patterns of human preference. This means that much of the development of agricultural technology must be undertaken in the regions in which, and under the conditions for which, it is designed to be used. Thus, by implication, at least the final stages of the research process must be accomplished in each region of each nation— and for each commodity of interest.

Crop varieties must be developed, or at least tested, in each locality. The same principle applies to techniques of fertilizer placement, timing, and amount; to measures for disease and insect control; to quantity and timing of irrigation; to feeding and management of animals; and to any other variable affected importantly by environment. Consequently, agricultural technology suited to one environment may have limited suitability to others that differ significantly from it. It is particularly significant that much of the technology developed in temperate regions is not applicable to the tropics; this should be expected, since scientists of the developed nations have long accepted the need for combinations of materials and techniques specifically designed for each season, in each locality, within their own countries.

Because of these limitations, modernization of agriculture in the developing nations is not a package that could simply be purchased if funds were available. It can be accomplished only by developing an infrastructure that will enable informed farmers to bring appropriate inputs to bear at the right time. Development of this infrastructure—experiment stations, extension agents, diverse industry, transportation, credit, and so on—is largely the responsibility of governments. The developed nations have had experience in these matters and by sharing their experience they can do much to achieve increased food production.

Other Factors in the World Food System

AFFLUENCE

As per capita income rises, human beings seek diets that are richer in variety and more nutritious, diets containing less carbohydrate and more fat and protein. To the extent that the change in diet entails consumption of fish and of animals that forage on grasses man cannot eat, the change enriches and supplements the diet. But if the livestock or poultry ingest food that might otherwise be consumed directly by man, there is the possibility of a shrinkage in the absolute food supply, since grain-fed animals use 3–10 calories of grain for each calorie of meat produced. About 40 percent of the world's livestock eats vegetable matter that could be directly eaten by man; indeed, three fourths of the grain grown in the United States is fed to animals. In all, the billion people of the developed world annually feed to livestock enough vegetable matter to serve as the sole sustenance of about 2 billion people. Obviously, such a society appears to have a very high per capita consumption of cereals.

In the United States and Canada, for example, per capita use of cereals approaches three fourths of a ton per year, of which only about 150 lb per year are consumed directly. In consequence, persons in these countries consume, on the average, directly and indirectly, an equivalent of 10,000 calories per person per day of primary agricultural products.

Per capita consumption of animal products in most other developed countries, notably those of Western and Eastern Europe and Japan, is considerably less than in North America but has been increasing rapidly.

This tendency in North America seems to have leveled off, but the trend in Europe, Japan, and the Soviet Union and among the higher-income groups of the developing nations may be expected to continue for a long time unless purchasing power is diverted in order to defray energy costs. Most of these countries lack the capacity to satisfy their demand for animal products entirely from indigenous sources. As a result, they are importing increasing amounts of livestock products and of feed grains and soybeans with which to expand their own livestock production. This rising demand exerts substantial upward pressure on the world price of cereals, and the price decreases the availability of the cereals in the lower-income countries (see Table 9).

This is not, of course, to say that voluntary reduction in consumption of meat and poultry automatically renders grain available to the hungry elsewhere. Reasons why additional grain might not become available are stated below.

- Poultry and swine are fairly efficient converters unless overfattened. Milk and egg production is of great nutritional importance, and the meat of milk cows and hens is highly acceptable. Cattle and sheep can be range-fed on lands that are not amenable to cultivation, and then fattened briefly, rather than being overfed in a feedlot to produce marbling. Because it contains less fat, meat from range-fed animals may be more healthful than meat from animals fed in feedlots.

TABLE 9 Annual Per Capita Grain Consumption in Selected Nations, 1964–1966 Average[a]

Nation	Grain Consumed Directly (lb)	Grain Consumed Indirectly (lb)	Total Grain Consumed (lb)	Grain Consumed as Multiple of Indian Consumption
Canada	202	1,791	1,993	5
United States	200	1,441	1,641	5
Soviet Union	344	883	1,227	4
United Kingdom	169	856	1,025	3
Argentina	223	625	848	2
West Germany	160	588	748	2
Mexico	305	242	547	2
Japan	320	211	531	2
China	312	118	430	1
India	288	60	348	1

[a]Adapted from Brown and Eckholm (1974a).

- In any case, with reduction in grain consumption generated by all such practices, including diminution in total meat consumption, the resulting grain supply can find its way to the poor and hungry in other lands only if international societal mechanisms have been developed for this purpose. The farmer must continue to perceive a market for his products, and all the subsequent costs must be met somehow if the products are to be processed and shipped. At a time when all primary products of American agriculture can be readily sold, largely to other affluent nations, and there are almost no reserves, it must be realized that there is a need to protect the domestic consumer against inordinate price rises. It must also be realized that concessional sales and food aid are no longer to be thought of as a by-product of a program to protect the domestic farmer; they are a direct contribution by the American people.

WEATHER AND CLIMATE

Variations in climate show enormous changes when viewed over very long periods of the earth's history, and the adaptation of man and his agricultural systems could be seriously disrupted if any extended change of temperature or rainfall patterns should occur. Consequently, trends in temperature or rainfall patterns require close scrutiny in any analysis of the food situation.

This set of considerations must be appreciated on two time scales. In any decade, irregularities in rainfall patterns that are capable of inflicting enormous damage to agriculture are likely to occur. In addition, long-term climatic trends may have major significance for agriculture. It is well known that for hundreds of millions of years the climates of different regions of the earth have undergone great changes. For the past 10,000 years, climates in middle latitudes have tended to become warmer, but substantial fluctuations have been superimposed upon this trend—i.e., intervals of 50 to 100 years when the climate became colder (Bergthorsson, 1969).

The mean temperature of the northern hemisphere reached a maximum about 1940. Since that time there has been progressive cooling—about 0.1° C per decade—that appears to be bringing mean temperatures to the levels of a century ago. Concern is expressed over the possibility that this seemingly small change is the onset of a continuing trend and is not merely a transient aberration (Bryson, 1973). In evidence is the observation that the area of winter snow cover and pack ice increased by 12 percent in recent years (Kukla and Kukla, 1974) preceding the anomalous crop summer of 1972. That was also the coldest year on record over much of Canada; every weather-reporting station was below the 1930–1960 "normals."

Pack ice appeared in Iceland in quantities unexperienced in this century, and summer temperatures declined dramatically. The running 5-year mean sea surface temperature recorded by the nine North Atlantic weather ships declined almost steadily since 1951–1955—from 12.05° to 11.48° C in 1968–1972 (Frejka, 1973; see also Figure 3). This drop occurred at the northern edge of the Gulf Stream, seemingly shifting it southward and thereby shortening the growing season in England by 2 weeks (Kukla and Kukla, 1974). Other anomalous weather patterns occurred at the same time: Temperatures and currents in the Pacific were changed, and growing periods in Canada and the Soviet Union were shortened. But it is not clear that all these changes were

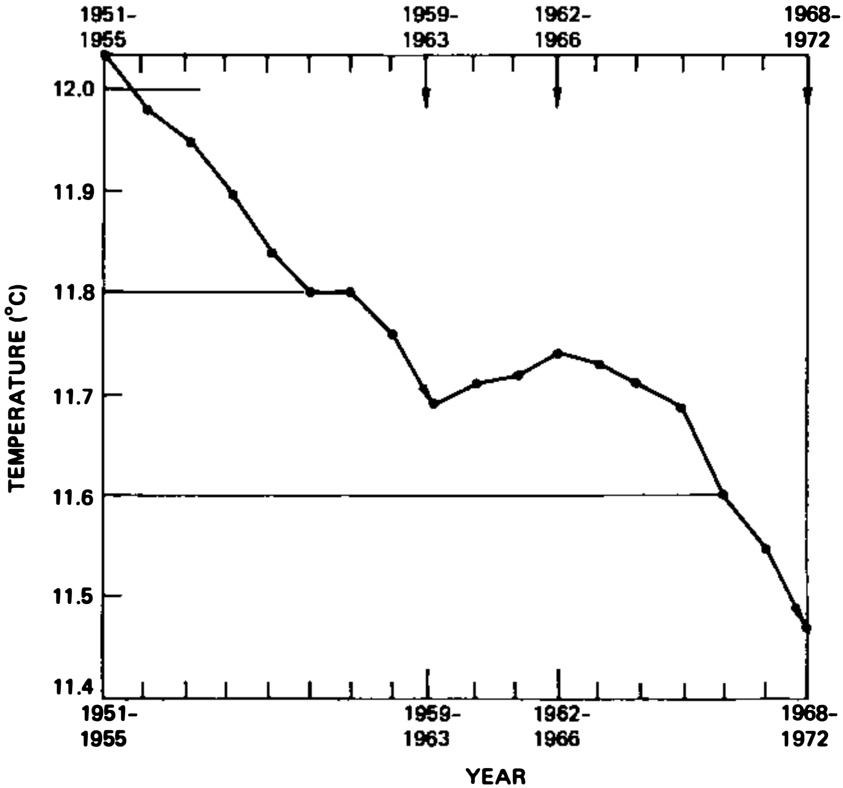

FIGURE 3 Running 5-year mean sea temperatures for the nine North Atlantic Ocean weather stations. (Adapted from Rodewald, 1973.)

associated with a basic change in climate patterns. The important question is whether these events mark the beginning of a long-term trend or are only unusual excursions from a norm. Should they be the former, world agriculture in the historically productive midlatitudes would suffer.

To some students of climate these considerations indicate that the last century, during which the human population burgeoned, was not "normal" or "typical" but, rather, extraordinarily equable and favorable for agricultural production. Should the cooling trend continue, should the fertile northernmost plains be taken out of agricultural production by contraction of the growing season, the result could be serious indeed and would exacerbate the problem of feeding the growing populations in tropical and subtropical regions.

FOOD RESERVES AND AID PROGRAMS

Direct food aid has constituted about 15 percent of total official developmental assistance in recent years. The most important commodity in food aid has been wheat, of which 10–15 million metric tons per year have been provided. Various difficulties have plagued food aid activities in the past, including the fact that receipt of food aid stocks can seriously distort trade patterns and, perhaps, undermine the incentives for agricultural production in the recipient nation. Yet food reserves, held somewhere, provide the only means of promptly mitigating national food disasters. In recent decades, the existence of food surpluses, especially in the United States, has made it possible to mitigate a number of such emergencies. With the U.S. surplus now depleted, the potential for buffer action has been correspondingly lessened.

Over the past three decades, North America—particularly the United States—has emerged as the world's breadbasket. In fiscal year 1974, the continent exported enough grain to feed about 500 million people on a minimal diet, although, as we have noted, much of this was actually used to feed livestock and poultry. In the same period, Australia and New Zealand, the only other net exporters of importance, together shipped about 6 million tons. All other major regions of the world were net importers. In the long term, none of these regions can look indefinitely to such imports for its nutrition; each must strive for basic nutritional self-sufficiency. Since, however, the distribution of favorable climates and soils, like the distribution of fossil fuels and of many other minerals, is highly uneven and the agricultural productivity of many developing nations cannot be expected to increase sufficiently for decades, the growth of populations in the developing nations will necessarily continue to generate a use for any available world food surpluses.

One of the consequences of the World Food Conference has been the establishment of a Committee on World Food Security, which is charged with recommending design and management schemes for a food reserve system. The need for such reserves is particularly obvious at this time, when grain reserves in the United States are so low that it is difficult to make a major response to shortages elsewhere and when we are not in position, either, to provide large amounts of more concentrated sources of protein to meet the needs of vulnerable population groups, especially children.

Contributions to world food stocks could be made whenever and wherever surpluses occur, with both exporting and importing nations holding agreed-upon minimum levels of stocks. Obviously, the United States would be the main contributor to this reserve. A system of this kind could also provide a measure of price stability in the world food economy, which would be in the best interest of all.

In addition to mechanisms for building international food reserves, we need a plan for distributing the supplies as needed and for determining criteria for payment by the recipient nations. Obviously, the plan should minimize interference with agricultural production and pricing in those nations deeply involved in crop production. Questions about overall control of reserves and their siting, sharing of costs, and conditions of release must be equitably resolved.

Increasing the World Food Supply

As we have seen, world agricultural resources are not homogeneously distributed around the planet. Climates, soils, terrain, water, and minerals vary in their distribution, as does the density of human populations. North America can produce enormous food surpluses, but in many of the developing countries of the world, people are destined to strive, for decades, to produce a nutritionally adequate diet. In some areas, including Western Europe and Japan, agriculture is capable of sustaining a reasonable state of health, but diets are greatly enriched by imports. Our concern, however, is for those large areas where basic food production barely suffices to support the populations and where occasional partial crop failures mean widespread malnutrition or famine. (See Figures 4 and 5.)

DEVELOPING AN EFFICIENT AGRICULTURE

The great challenge is to promote in the developing nations an efficient agriculture that will maximize production of crops by techniques that are adapted to the local soils, climate, customs, and demands. In addition to fostering development of the infrastructure of modern agriculture, the governments must assist in making capital available for expansion of irrigation, reclamation of land, limited mechanization, and processing and storing facilities.

It is obvious that such agriculture depends on research and the application of research findings. Productivity (yield per hectare)

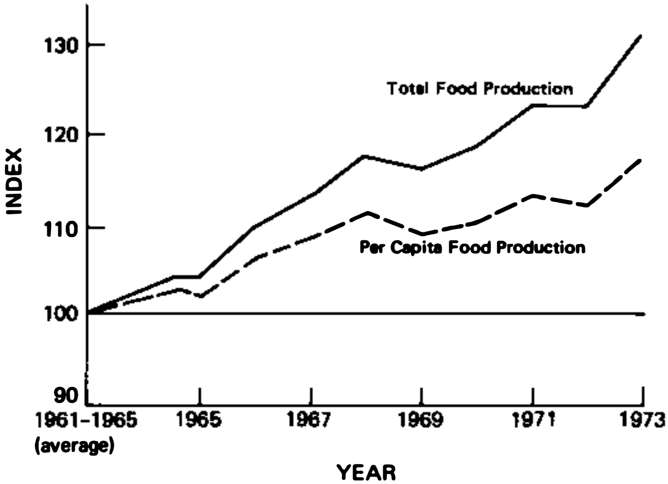

FIGURE 4 More developed countries: Total and per capita food consumption rises substantially. (Reprinted with permission from Brown and Eckholm, 1974a.)

increased about 1.75 percent per year from 1930 to 1972 in the United States, and it is estimated that 80 percent of that increase derived from agricultural research and extension activities. Although some of this research can be done elsewhere, the last phases must always be

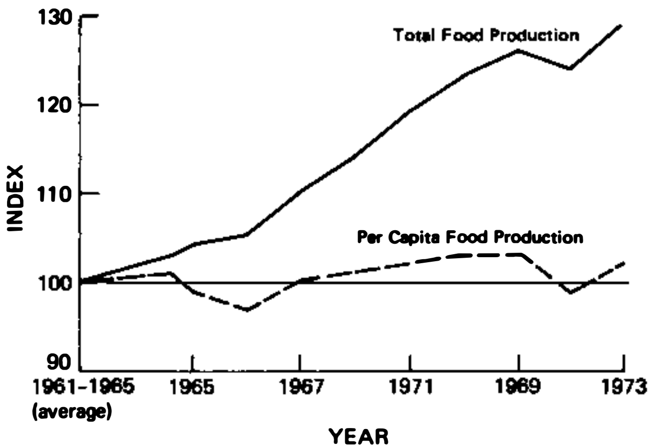

FIGURE 5 Less developed countries (excluding communist Asia): Population growth absorbs increases in food production. (Reprinted with permission from Brown and Eckholm, 1974a.)

undertaken locally. The agricultural establishments—universities and industrial concerns—of the developed world can be expected to cooperate in the development of appropriate institutions in the developing nations and in the training of their staffs, but the local institutions must be planned and designed by the developing nations in accord with their own requirements. The nine international agricultural centers have been greatly strengthened since formation of the Consultative Group for International Agricultural Research in 1971, and universities in North America and Europe have expanded their participation in agricultural work in the developing countries. Much remains to be done, however, before each country will have access to technical resources adequate to manage its own agricultural problems. Although loans and credits to developing nations have been of great assistance—those from the World Bank more than doubled between 1970 and 1972 (from $419 million to $937 million)—the fact is that the per capita production of the developing countries has not risen significantly since 1968, largely, of course, because the gains in production have been matched by population growth.

In many instances, farm productivity can best be achieved by enhancing agricultural productivity of small farms and by fostering rural development. Again, these activities are essentially a responsibility of government.

Improvement of agriculture in developing countries must come primarily through increased production of the conventional, basic crops and livestock. It will be useful, however, to consider also some additional opportunities for expansion of the food supply.

Food resources may be significantly supplemented by the development and exploitation of various new, unconventional foods. "Single-cell protein" derived from yeast, or from bacteria grown directly on agricultural wastes or on petroleum hydrocarbons, is already proving practical for animal feed in certain industrialized countries where their high cost is acceptable. Some of these foods may be useful as supplements in human diets when their high costs decline sufficiently and their physical and biological properties render them acceptable for this purpose (Protein Advisory Group, 1972). Fish protein concentrate is less likely to make a major contribution because the potential supply of fish is limited and the costs are relatively high.

Various forms of aquaculture are being developed. A number of freshwater, brackish, and marine organisms can be raised under controlled conditions and may be expected to contribute to the quality of the diets of certain populations. Artificial freshwater pond operations in Asia and Africa, brackish water production of shrimp and fish in certain countries and the controlled rearing of trout, salmon, carp, and catfish are increasing in importance. The possibilities for exploiting underutilized marine species are more limited, but this approach is well worth pursuing for crustacea and mollusks as well as fish.

INCREASING U.S. AGRICULTURAL PRODUCTIVITY

When the report *The World Food Problem* was prepared in the 1960's (PSAC, 1967), the rapid growth of world dependence on U.S. food exports was not anticipated. Moreover, the extent to which American agricultural products would enter the export market was not appreciated. Despite extensive domestic use of grains, the agricultural enterprise has provided the United States with a major benefit in export trade. Whereas nonagricultural trade accumulated a deficit of $8.4 billion in 1974, agricultural products provided a trade surplus of $11 billion. Indeed, in the past 15 years, agricultural products have constituted an ever-growing part of the total U.S. export trade.

Nonetheless, there is reason for concern about the vigor and growth of the scientific and technological effort underlying agriculture in the United States. In the 1950's and 1960's the nation was burdened with heavy food surpluses, and there was an understandable reluctance to invest heavily in agricultural science and technology; some took the view that further increases in the rate of productivity would only aggravate the surplus situation. In that climate of opinion, research and training in agriculture did not prosper as they would have otherwise, and they were sometimes provincial in orientation. Now is the time to inject new vigor and incentive into our own agricultural technology and into the scientific research effort that underlies the agricultural enterprise.

Productivity of U.S. farms could be increased appreciably if current technology were fully applied. The extent to which technology is less than fully utilized varies from crop to crop. Some increases can be achieved on lands now being cultivated; others may come as a result of changes in land use. But in the last analysis the extent to which productivity is increased will depend on the extent and permanence of the economic incentives that are perceived by the farmer.

The dramatic changes in cost and availability of fuels and fertilizers must be expected to impose many new constraints on agricultural production. A vigorous and imaginative research activity will be essential in meeting these changing stringencies.

New Research Priorities

An important element in resolving the problems here considered, particularly over the long run, will be the effective prosecution of well-designed research—both basic and applied—that bears not only on scientific and technical advances but also on better understanding of the ways in which social and political institutions can effectively apply new knowledge to stabilizing populations, increasing food supplies, and making more rational use of available food resources. Some examples of needed research and development have already been noted; others are presented below.

HEALTH

Evidence suggests that until there is reasonable assurance that children have a good chance of reaching maturity, their parents are poorly motivated to reduce fertility. This demographic transition appears to be particularly applicable to the most underprivileged, who have had the most bitter experience. Research is required to establish how best to provide an adequate balanced diet to the children of each developing area.

Established methods of sanitation and hygiene should be instituted wherever they are lacking, and education in sanitation, hygiene, and nutrition should be made available.

There is urgent need for research on better methods of preventing infectious diseases still seriously affecting the populations of many developing countries, such as diarrheal diseases, malaria, and schistosomiasis.

FERTILITY CONTROL

The effectiveness of fertility control methods is limited by accessibility to contraceptive materials and by motivation for their use. Clearly, it is possible for people to control fertility without mechanical assistance, but there is little evidence that they wish to. Were the social and economic goals of "development" attained, fertility would be expected to decline as it has in all other countries that have already achieved development. But since those goals are far from attainment, research is required to identify means for hastening reduction in fertility in the interim.

Among the many facets of this problem, one may list research in human fertility and reproductive physiology and other efforts to develop new, cheap, safe, effective means of limiting fertility through individual choice; research on social and psychological factors in motivation for fertility control; research on how best to produce and distribute contraceptive materials; analysis of the linkage between socioeconomic progress and fertility control; and research on opportunities to improve the status of women. It is well to note also the need to agree on arrangements whereby new orally administered contraceptives may be acceptably appraised for their efficacy and safety in human subjects.

AGRICULTURAL EFFICIENCY

The world system for production, storage, and distribution of food is in need of substantial modernization and expansion. In part, increase of productivity requires new knowledge and methods; in part, it can be accomplished by more effective application of existing knowledge. Most of the research on new methods must be conducted in the areas where the results are to be applied. Problems related to the distribution, storage, processing, and preservation of crops, products, and by-products may well be susceptible to the intensive application of existing knowledge, skills, and techniques, but remedies would surely be found more quickly if research were addressed to the specific problems of each area.

The question of how much the major agricultural areas of the world, including the United States, could produce if maximally worked is currently unanswered. The incentives to which farmers respond, in the few countries that produce grain surplus, would in large measure dictate the answer to this question. Nonetheless, it would be wise to make a serious effort to ascertain the long-term sustainable productive capacity of currently available farm land and of land that can be turned to agriculturally productive uses at costs that seem within reason. It would also be wise to determine the effects of such maximal production on the consumption of nonrenewable resources and on the quality of the environment. It is probably pointless to ascertain total absolute capacity unless it is assumed that, under some circumstance, the production of food will have the highest priority call on resources and that farmers will have adequate incentives.

The important question is: What can be done to enhance productivity? Three components of this question are: What can be done by using existing research information? What can be done by significantly increasing funding of research? What can be done by using marginally productive land resources at acceptable costs? For the immediate future, it is essential that research be undertaken along the various lines noted below and that governments provide the funds to make the programs possible. It is also desirable to examine unconventional approaches, high-cost or high-risk options, and the possible benefits to be derived from massive diversion of resources. Specific highly desirable research programs requiring increased emphasis are listed below:

- Genetic improvement of food crops for improved agronomic and nutritional characteristics
- Protection against increasing genetic vulnerability of crops and livestock, including the maintenance of gene pools and genetic stocks, and the introduction of new genetic material
- Intensification of research on nonleguminous nitrogen fixation, including possible introduction of nitrogenase by "genetic engineering"
- Intensification of research on disease and mechanisms of disease resistance in crops and livestock
- Studies of climatic variations as they may affect food production
- Development of agricultural practices that are less demanding of such high-energy components as fuel, fertilizer, and pesticides
- Development of new biological and chemical means of pest control
- Development of agricultural practices that conserve and make optimal use of available water, including measures to avoid salination of irrigated lands and efforts to develop agriculture in arid regions
- Improvement of methods for harvesting, transportation, storage, processing, preparation, and marketing
- Development of agriculture in cleared tropical forests, including improving mechanisms for managing lateritic soils

- Improved efficiency of aquacultural production systems, including (1) determination of the maximal potential of marine and brackish-water fisheries for sustained yield and development of techniques for improving yields of marine organisms through various types of artificial culture or impoundment and (2) improved techniques for maximizing the productivity of freshwater ponds
- Development of unconventional or novel sources of food and feed

New knowledge and techniques for its application in conjunction with or in place of traditional practice may entail difficult social change and require innovative institutions. If these efforts are to be successful, the developed world, through its communications technology, its research capacity, its trained and dedicated experts, and its financial resources, must expand its collaboration with the developing world. Unless this collaboration in research, education, and development is effective, the chances of avoiding disaster seem slim indeed.

Conclusions

The continued growth of world population in the face of heavy constraints on food and energy production is a critical issue. This is not to say that the array of problems presented is unmanageable; indeed, in recent years, there have been a number of hopeful advances, suggesting that efforts now to deal with the situation could be more successful than might have been possible at the time of earlier comprehensive appraisals of the world food and energy situation (Hubbert, 1962; PSAC, 1967; NAS, 1971).

Certain findings of these reports are sufficiently applicable in 1974 to bear repeating:

- . . . over a billion births will have to be prevented during the next 30 years to bring down the world's population growth rate from the present 2 percent per year to an annual rate of 1 percent by the year 2000. The task may well be the most difficult mankind has ever faced. . . . (NAS, 1971, Vol. 1, p. 4).
- The scale, severity, and duration of the world food problem are so great that a massive, long-range, innovative effort unprecedented in human history will be required to master it. (PSAC, 1967, Vol. I, p. 11)
- Food supply is directly related to agricultural development and, in turn, agricultural development and overall economic development are critically interdependent in the hungry countries. (PSAC, 1967, Vol. I. p. 11)
- A strategy for attacking the world food problem will, of necessity, encompass the entire foreign economic assistance effort of the United States in concert with other developed countries, voluntary institutions, and international organizations. (PSAC, 1967, Vol. I, p. 11)
- . . . during the last century or two . . . the pattern of change which we have observed . . . has been of almost continual growth. . . . Yet when reviewed in

historical perspective, we have seen that . . . the rates of growth we have been witnessing, instead of being the "normal" order of things, are in fact the most abnormal in human history—the usual, or normal, shape of affairs being one in which the magnitudes of various human activities have been subject to an almost imperceptible rate of change. (Hubbert, 1962, p. 124–125)

The world population/food situation has shifted in several important ways since publication of these earlier assessments; the spread of family planning, especially in the developed countries, has been an important progressive step. There have been changes in economic conditions, including rising costs and increasing affluence in a number of countries. The gains in agricultural productivity have been greater than anticipated, but there is cause for alarm in the fact that the developing countries are failing to gain in per capita production of food. The stringencies in fuel supplies and the rapid increases in cost of agricultural materials (machinery, fertilizer, pesticides) have markedly complicated the food production picture. Progress has been made, but the new complications further aggravate an already difficult and complex set of problems.

The problems associated with meeting overall food needs for the next 5 or 10 years appear manageable, provided there is a concerted effort to increase food production globally, and provided there is no serious setback to production in the principal food-producing regions. The outlook for subsequent decades is alarming unless real progress can be made in reducing the rate of population growth. On any time scale, the problems of southern Asia appear large and more difficult than those of any other region; without early and marked decline in the rate of population growth, those problems may become unmanageable.

In the very long term, the carrying capacity of the planet for human beings, in the sense of potential food supply, can suffice for decidedly larger populations than are likely to be realized. But a critical factor in the quality of life will be the actual level of population prevailing at the time equilibrium is achieved. If that level is too high, the resultant social and political instabilities may well lead to entirely different "solutions" to these problems.

Recommendations

1. The first priority of the developed world must be to ensure that adequate food supplies are produced and that reserves are created to mitigate the otherwise catastrophic effects of almost inevitable crop failures. To achieve this will require a major expansion of agricultural science and technology.

2. The developing world must increase its capacity to produce, store, and distribute food effectively. The developed world will have to support much of this effort by providing capital, expertise, research capacity, and means for dissemination of new knowledge.

3. There should be a careful study of the subtle problems associated with the question of how best to strike a balance in the disposition of North American agricultural products among domestic demand, demand on world markets, the need for maintaining some reserves against fluctuations and crop failures, and the need for nutritional supplementation and relief of acute famine.

4. In the interest of achieving an acceptable food/ population balance, national leaders should take positive steps to enunciate national goals for stabilizing population and for food production and should initiate programs to achieve those goals.

5. To assist developing nations in achieving their goals, the developed nations should increase their support of efforts of the United Nations to stabilize populations and efforts of those private and bilateral governmental arrangements already dedicated to control and eradication of disease, to nutritional education and research, to research on human reproduction, and to development and dissemination of contraceptive materials and information.

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