McGRAW-HILL ENCYCLOPEDIA OF FOOD, AGRICULTURE & NUTRITION

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DANIEL N. LAPEDES
Editor in Chief

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Preface

Food is the source of energy for the maintenance of life. Throughout history, the primary concern of all civilizations has been to produce adequate supplies of food. This has not always been realized, either qualitatively or quantitatively. Today, with 25% of the world population living at or below subsistence food level, a crisis exists.

The problem is complex, having sociological, economic, and technological aspects, and is most acute in the Third and Fourth Worlds. In these regions, population growth outpaces food supply, per capita income is low, and capital investment, particularly in the Third World, has shifted more to industry and away from agriculture, even though these developing countries are agrarian. Where food supplies are limited and poverty prevails, people suffer from chronic malnutrition and starvation, conditions which only serve to reinforce their poverty.

There are several approaches to solving the world food problem. Agriculture plays a key role by providing the means for increasing productivity. Scientific and technological advances in the industrialized world have fostered the development of more efficient farm machinery; more effective chemical fertilizers, insecticides, and herbicides; improved crop varieties and animal breeds; and new farming methods, such as multiple cropping and reduced tillage farming. However, while some of these advances, particularly mechanization and the breeding programs of the Green Revolution, have been successfully applied to large commercial farms, their usefulness must be adapted to subsistence-level farming. Profitable agriculture is thus technologically feasible for the Third and Fourth World countries, but it will require large capital investments from the developed countries and restructuring of the economies within the developing countries.

Another approach in dealing with the problem is to seek new food sources and products, especially those rich in protein. One important source of protein is fish and other seafoods. Another source is vegetables. This type of protein is relatively inexpensive and provides a nutritious substitute for animal protein.

The world population-food crisis is not intractable, but does involve more than increasing food production and decreasing population growth rates. Lack of food also results from crop failures, inefficient food supply systems, maldistribution of food within and between countries, and geographic and climatic restraints. Future success in feeding the world will depend on a coordinated program of action by business and government and on a balanced industrial and agricultural effort.

The *McGraw-Hill Encyclopedia of Food, Agriculture & Nutrition* is designed to inform the student, librarian, scientist, teacher, engineer, and lay person about all aspects of agriculture; the cultivation, harvesting, and processing of food crops; food manufacturing; and health and nutrition—from the economic and political to the technological. The Encyclopedia is arranged in two parts. The first part contains five feature articles which present an overview of the world food problem: Feeding the World, Climate and Crops, Energy in the Food System, Food from the Sea, and The Green Revolution. The second part, with its 400 alphabetically arranged articles written by specialists, contains information on such subjects as food engineering, pesticides, agricultural geography, vitamins, irrigation of crops, breeding of animals and plants, and all important food crops. The articles, some drawn from the *McGraw-Hill Encyclopedia of Science and Technology* (4th ed., 1977) and some written especially for the volume, are included on the recommendation of the Board of Consultants. All articles are signed by the authors, who are listed with their affiliations in the List of Contributors. The articles are cross-referenced to other articles on related subjects. An appendix details the composition of prevalent foods from the standpoint of caloric, protein, carbohydrate, fat, mineral, and vitamin content. There is also an analytical index which provides quick and easy access to the subjects in the volume.

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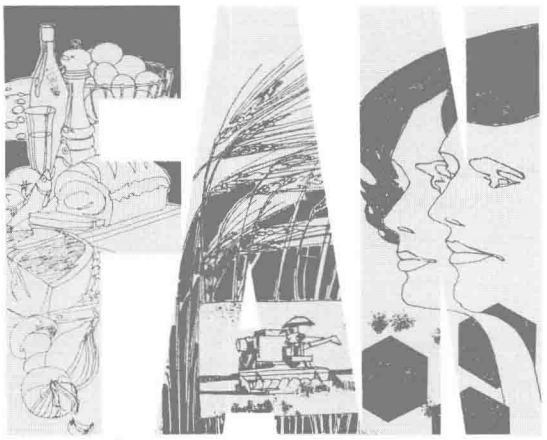


FEEDING THE WORLD

Douglas N. Ross

The population-food crisis in the less-developed regions of the world appears massive and intractable. Despite attention at highest governmental levels in Bucharest at the 1974 World Population Conference and in Rome at the 1974 World Food Conference, serious doubts among groups concerned with both the population and food crises continue to be reported in the public media. Of special concern is the ability and the will of political and economic institutions to respond adequately. The potential for tragedy is great; even if the world succeeds in feeding those presently in need, it may only be deferring the starvation of many more to the future, unless available food supply keeps pace with population growth or population growth is curtailed.

Over 1 billion of the world's 4 billion people live at or below subsistence food levels, mostly in tropical regions which are characterized by high human fertility rates, low per capita income, and low capital investment in agriculture. These economically marginal regions of South Asia, Central Africa, and South America are grouped into a Third World which has extensive natural resources essential to the industrialized world, and a Fourth World which is deficient in everything but people. The resource-rich Third World has the leverage to force industrial countries' attention to its food and development needs; the Fourth World must rely primarily on humanitarian appeals.

POPULATION AND FOOD

In his 1798 formulation of the population-food dilemma, Thomas Malthus claimed that if the food supply were fixed while the population grew, the only check to the ultimate size of the population would be starvation. While Malthus underestimated the rate of technological change and the effect of human ingenuity, the hypothesis does state the diluting effect on the creation of wealth of changes

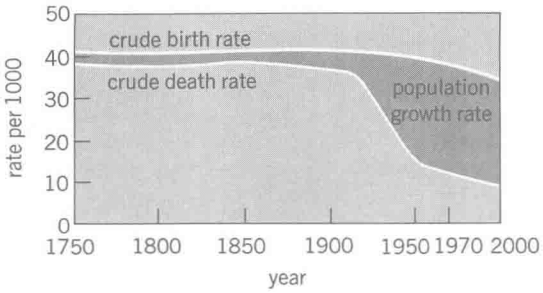


Fig. 1. Antecedents of the population explosion in developing countries. *(From GENERAL ELECTRIC–TEMPO, The Economics of Slowing Population Growth, Center for Advanced Studies, Santa Barbara, CA, 71 TMP-42)*

in population size. and in context, it is not unreasonable. Throughout history, the bane of human existence has been "killer" epidemic disease, such as plague, typhus, cholera, and measles, which usually followed periodic famine. Such natural disasters counterbalanced high birthrates with high death rates, which consequently kept population size in check. In the 17th century something happened: the world's population growth rate (that is, the difference between the birth and death rates—until then about 0.056%, or 560 persons per year for each 1 million population) began to increase. In 18th century Europe, this rate increased first to 0.5% and then to 1.5% (or to 5000 and then to 15,000 per 1 million), due primarily to a decline in death rates (Fig. 1). The population "explosion" has been ascribed to three main factors: (1) public health improvements—largely preventative rather than therapeutic—including means for the detection and containment of infection; (2) the decrease and eventual disappearance in the 19th century of infanticide; and (3) an increase in the food supply. The effect was that instead of taking 1000 years as Malthus predicted, the population doubled within 100 years. By the beginning of the 19th century the Earth's population had reached 1 billion. By 1900 the world's population had reached an estimated 1.7 billion and today is estimated at over 4 billion (Fig. 2). Society has yet to discover and implement socially acceptable means of population control worldwide.

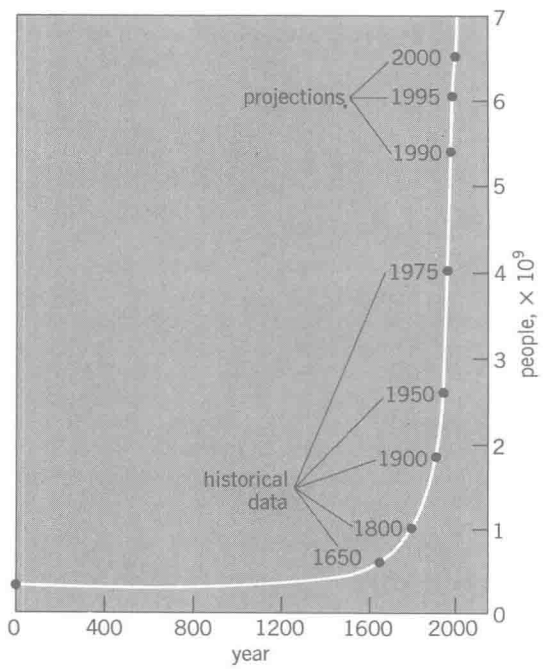


Fig. 2. World population growth. *(From M. Mesarovic and E. Pestel, Mankind at the Turning Point: The Second Report to The Club of Rome. Copyright © 1974 by M. Mesarovic and E. Pestel. Reprinted by permission of the publishers, E. P. Dutton)*

The 20th century has seen the population growth rate of most industrialized countries in the North Temperate Zone fall back to a range of 0.6 to 1.3% (still not a zero population growth rate). Even at this rate the "projective" effect on the United States is still the addition of 25 "Philadelphias" (population 2.3 million) between now and the year 2000.

Current estimates place the world's population growth rate at about 1.8% per year, which means that the world's population may double in about 33 years. Figure 3 illustrates the alternatives. In Fig. 3*a*, if present population growth rates continue, then by the year 2000 the Population Reference Bureau estimates a world population of 7.2 billion, 75% of whom would be living in less-developed nations. Figure 3*b* shows that if the world's birthrate could be lowered from present levels to the replacement rate of two children per family, then the world's population could stabilize at about 6 billion by 2020.

Population growth. There is a "development race" between a growing population and an increasing food supply (or capital wealth). The numerical size of a country's population is thus less important to its economic advance than the rate of population growth. It is important to distinguish between them. A "large" or "small" population refers to the total size of the population—or labor force—relative to the availability of natural resources and domestic capital. When a large population also has a high population growth rate, as in India (610 million, with a 2.2% population growth rate) the population-economic situation is at its worst. Rapid population growth means that the population, on average, is younger, and therefore more dependent and less able to work (Fig. 4). Even relatively small-population countries face a tremendous "development race" handicap. Chilean political and economic leaders, for example, face a situation in which less than 25% of Chile's 10.5 million people have sewage facilities and less than 20% have adequate water supplies; 70% of the children are infested by parasites; and the rate of mental retardation approaches 40% in some severely malnourished social groups.

The advantages to a population growth rate below the rate of increase in gross national product (GNP) are that per capita income can increase and, at the same time, a larger percentage of the populace will be of an age to enter the work force (Fig. 5). The danger in a high population growth rate lies in the difficulty of increasing per capita wealth and the benefits of wealth—higher aspirations, greater savings, better education, more food, and more freedom for the mother.

Per capita wealth and population growth rates. In the less-developed nations with annual population increases of 2.5% and GNP increases of 5%, it

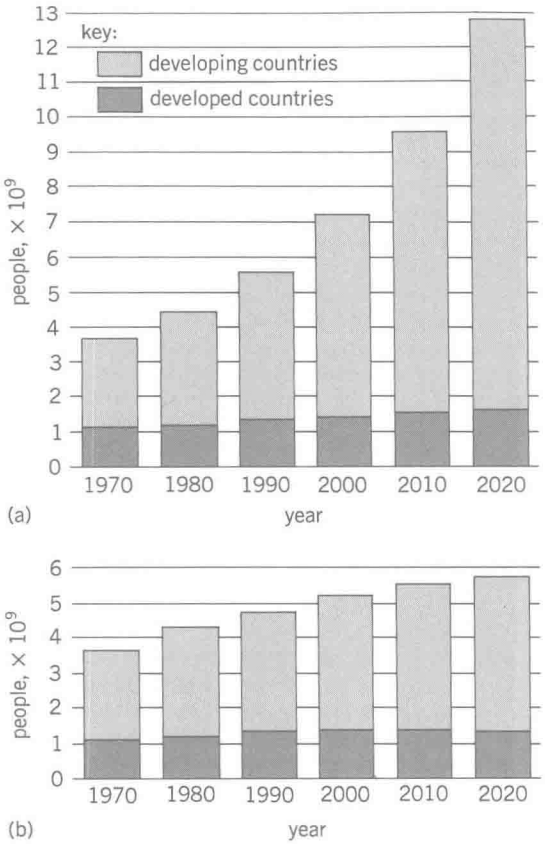


Fig. 3. World population growth, 1970–2020: (*a*) if number of children per family were to remain at the 1970–1975 level, (*b*) if an average of two children per family were reached by 1990. *(From United Nations, The Population Reference Bureau; and D. N. Ross, Understanding Population: A Short Primer and a Glossary of Terms, Inform. Bull. no. 18, The Conference Board, New York, 1977)*

takes about 25 years for per capita GNP to double from $200 to $400. In 1972, according to estimates made by the U.S. Agency for International Development (AID), the world average annual number of births per 1000 people was 32 and the GNP per capita was $904 (Fig. 6).

As Fig. 6 indicates, birthrates in the world's nations show a regular downward trend as GNP per capita increases. More than one-half of the world's people are represented by those countries (in the upper left corner of the figure) where GNP per capita is less than $500 per person per year, and birthrates range from 40 to 50 per 1000 people per year). Recent indications are that less disparity in within-country incomes is also conducive to lower birthrates. While industrialized-country levels of income may not be necessary for lower birthrates, one might conclude from the clustering of countries along the curve in Fig. 6 that a $1000–2000 per capita GNP is the minimum range in which a decline in the birthrate can be expected to occur.

FOOD AVAILABILITY

The problem of feeding people is only one of many interconnected human welfare problems both between and within nations. The solution of any of these problems is critically dependent on the solution of the others. If this approach is not taken, then the food problem either appears unsolvable or proposed solutions are simplistic. As an example, in less-developed countries a significant portion of the population, 62% in 1975, was directly or indirectly involved in agricultural production. Since a main cause of poverty is low agricultural productivity, that is, low yield per worker or per hectare, it is almost astounding that, with respect to nearly two-thirds of the labor force, on the average less than 25% of available investment funds went into agricultural projects. The far greater share, over the past 25 years, has been directed toward urban, industrial development, which has exacerbated population problems by stimulating rural-to-urban migration and which has reduced the food supply by taking capital and credit—one means of production—away from farmers.

Basic food requirements. The most intractable aspect of the food problem is the maldistribution of nutritious foodstuffs between and within countries. Within countries certain vulnerable groups—the poor, particularly women and children—bear the brunt of underconsumption. While climate, physical activity levels, and individual differences affect daily dietary needs, there is still severe undernutrition in terms of dietary energy (protein-calorie) supplies, particularly in Central Africa (Fig. 7). According to the United Nations Protein Advisory Group, the level for the United States—a high-income temperate-zone country—is 2600 cal (10,890 J) and 40 g of protein daily. For tropical-zone developing countries the level is 2300 cal (9630 J) and 38 g of protein per day. Malnutrition places heavy constraints on human potential, whether in a less-developed region of an affluent country or in a poor country. The United Nations World Food Conference Assessment of the World Food Situation estimated that about 25% of the population in developing market-economy countries has an inadequate daily intake of dietary energy as compared with 3% in industrial countries. *See* MALNUTRITION; NUTRITION; PROTEIN.

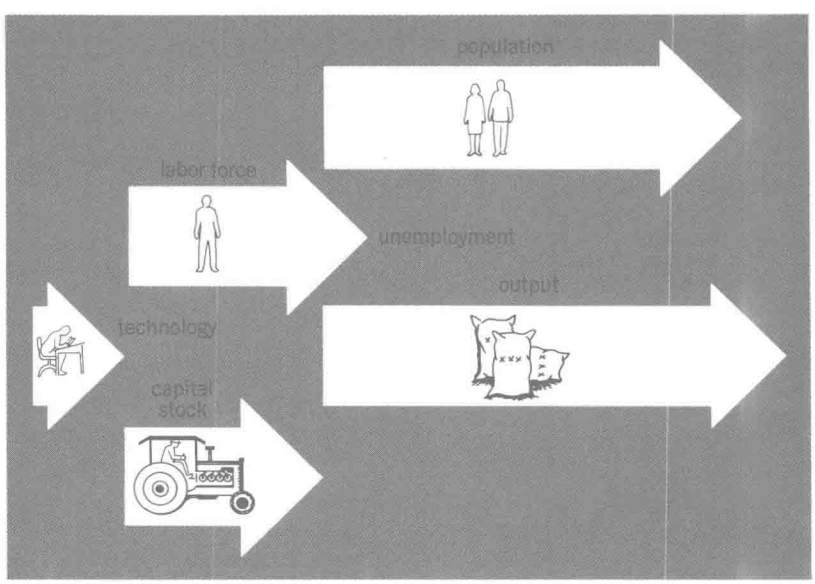


Fig. 4. The development race. *(From GENERAL ELECTRIC–TEMPO, The Economics of Slowing Population Growth, Center for Advanced Studies, Santa Barbara, CA, 71 TMP-42)*

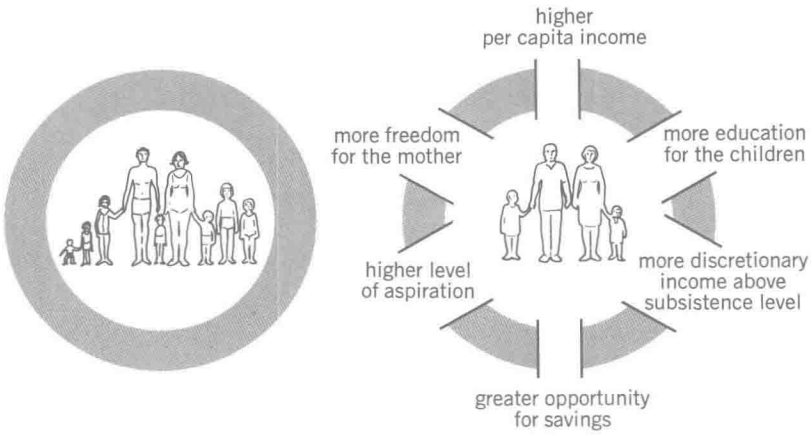


Fig. 5. Qualitative advantages of limiting family size.

Food versus people. Industrialized and less-developed countries have diverged markedly in per capita food production in recent years due to differences in both population growth rates and agricultural productivity. Of the 96 developing countries for which the Food and Agriculture Organization (FAO, the United Nations agency devoted to promoting efficient production and distribution of food and agricultural products) publishes data, food production kept pace with population increases in 51 and lagged in 45, in the 1961–1974 period. These 45 countries represent 40% of the total population of the developing countries. Figure 8 shows the precarious level of per capita food production in these 96 less-developed countries.

More food—higher capital costs. While the magnitude of the 1972–1973 per capita food production decline which triggered the World Food Conference of 1974 was not nearly so great as the decline during the famine of 1966, the situation today still requires constant vigilance and extreme efforts. Food production increases—measured as the food component of crop and livestock production—by FAO estimates have fallen from an average annual increase of 3.1% in the 1950s, through 2.8% in the 1960s, to a 2.2% level in the period 1971–1975. In part, this deteriorating rate of increase reflects the increasing difficulty of producing larger absolute amounts to equal the same percentage increase, and in part, reflects difficulties in extending cultivated areas and in raising yields. By current technological standards, 90% or more of the arable land in the developing regions is already in production (though yields are typically less than half of those obtainable with proper crop selection and fertilizer use). Capital costs which must be incurred to develop land and suitable water supplies depend, of course, upon project size, conditions, and complexity. In Colombia, for example, the average cost for irrigating new lands was $1150/ha in 1967—a tremendous burden for a country in which yearly per capita income is less than $500 and current capital investment in agrarian areas is not more than $150/ha.

More food—higher energy costs. The quadrupling of oil-energy prices accelerated the arrival of the food crisis. The low-income, high-fertility Fourth World regions do not now generate sufficient foreign exchange earnings to acquire energy resources, chemical fertilizers, and food. In addition, there are more subtle, but profound, difficulties. Scientific agricultural research is carried on primarily in the developed world—85% of the world's scientists work in developed temperate-zone countries. This has important ramifications. To illustrate, chemical nitrogen fertilizer is a major component of the "green revolution" input package of fertilizer, water, and high-yielding seed vari-

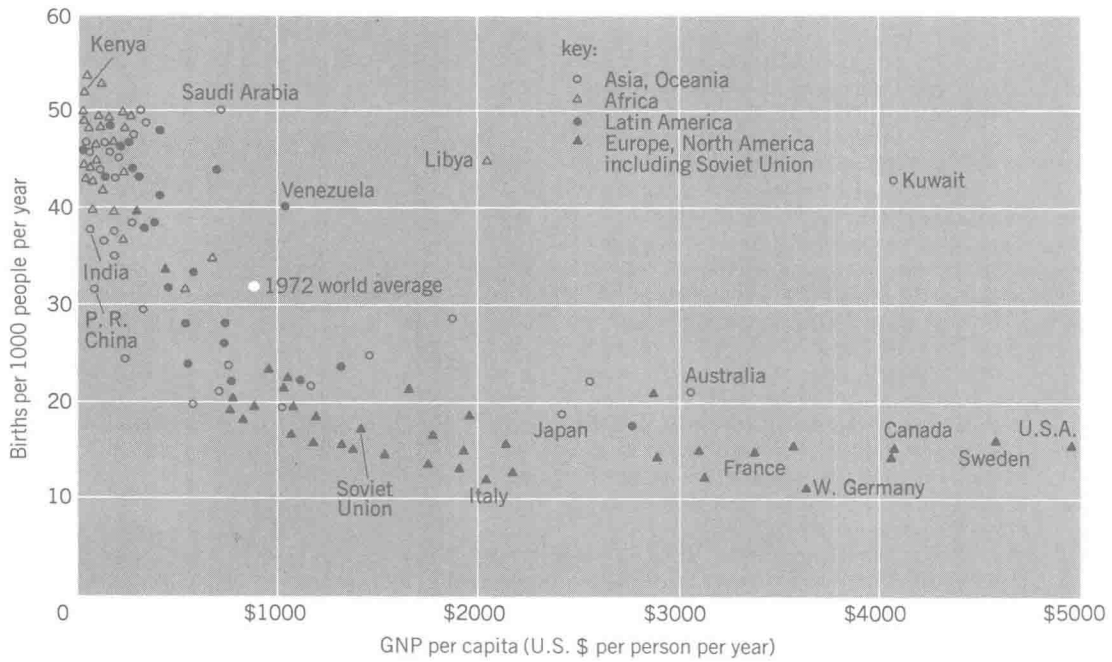


Fig. 6. National birth rates versus per capita GNP. *(From U.S. Agency for International Development, Population Program Assistance Annual Report Fiscal Year 1973, U.S. Government Printing Office, 1974; and The Conference Board, New York)*

eties. The problem with the best commercial method for producing artificial fertilizer is the high energy requirement. Thus, as the price of energy increases, the "appropriateness" of high-energy technology becomes more questionable. *See the feature articles* ENERGY IN THE FOOD SYSTEM; THE GREEN REVOLUTION. *See also* FERTILIZER.

More food—and the weather. In 1972 bad weather was widespread in Europe, the Soviet Union, the Far East, China, and North America, and total world food production declined in absolute terms for the first time in the post–World War II era. Foodstocks, in fact, have declined through 1975, which means that world food supplies have been dependent on current harvests for nearly 4 years. Meteorologists in general are now forecasting a change; some see a trend toward a warmer, others toward a cooler climate. As temperatures drop, the number of people sustainable by arable land also declines. Should the climate return to the level at the "Little Ice Age" of 1600–1850, India could support only three out of four people now living there; the Soviet Union would lose Kazakhstan as a vital grain-producing state; and Canadian grain export capacity would be reduced by 75%. Nevertheless, the world's political and economic leaders are unable to agree upon even emergency food stock reserves. *See the feature article* CLIMATE AND CROPS.

OPTIONS TO PREVENT MALNUTRITION AND STARVATION

This discussion focuses on the less-developed world, particularly the "bottom billion." From the viewpoint of the less-developed countries, there are essentially four interrelated options for improving food availability: (1) decrease the population growth rate; (2) hope for more food aid; (3) import more food; and (4) stimulate the productivity of the food supply system.

Decrease the population growth rate. According to the Population Council, a New York–based research organization, about 30 of 120 developing countries have official policies aimed at reducing population growth rates. Thirty others, which include most Latin America countries, have some family planning policies; the other 60 are "indifferent."

Not everyone agrees on the need to control population growth. Some argue that technology applied to the world's underutilized oceans, deserts, and jungles could provide a base to feed an additional 50 billion people. They suggest that many changes could be made in current practices to enlarge the Earth's carrying capacity. Other political leaders point to the drastic political consequences suffered by Indian Prime Minister Indira Gandhi's Congress Party, at least partly because of government forced-sterilization programs, and see this as an indication for caution in their own population programs.

These views overlook several important considerations: More intensive land use is already threatening ecologically marginal lands. Also, there is evidence that, in the 1974–1975 period of food production decline, the United States activated a "hidden" grain reserve—cereal feeding to livestock decreased 25% due to relative price changes in food and feed grains. In other words, the present food "reserve stock" is slack in the supply system.

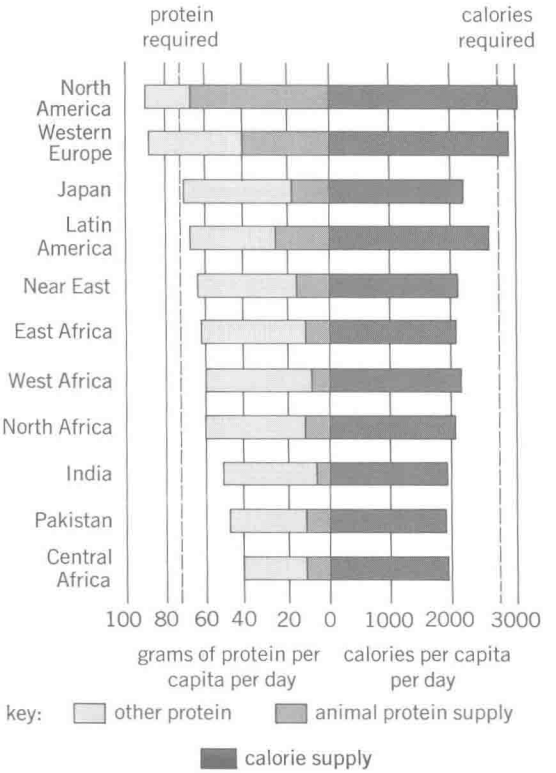


Fig. 7. Protein and caloric intake. Dashed lines indicate estimated North American protein and caloric requirements, based on diets sufficient to enable people to attain full body weight. *(From D. H. Meadows et al., The Limits to Growth: A Report for The Club of Rome's Project on the Predicament of Mankind, A Potomac Associates Book published by Universe Books, New York, 1972. Graphics by Potomac Associates)*

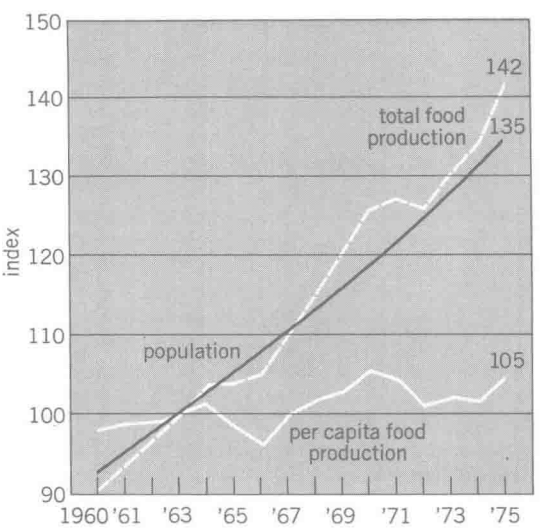


Fig. 8. Food versus people in the developing countries. Index: 1961–1965 = 100. *(USDA)*

Further, there is some evidence that less-developed countries birthrates are declining, due at least in part to the voluntary population programs of the past 15 years in India, Indonesia, Korea, Pakistan, and several Caribbean countries. The

Food shipments under P.L. 480, Title 1, 1960–1974*

Commodity	1960†	1965†	1970	1972	1973	1974‡
Wheat and products	8199	13,705	5765	4615	2517	1005
Milk (dried)	8	42	18	19	2	0
Rice	453	561	884	813	987	620
Corn, sorghum	787	728	1078	1217	1289	454
Vegetable oils	339	364	240	193	107	148

SOURCE: U.S. Department of Agriculture and Lester R. Brown with Erik P. Eckholm, *By Bread Alone*, Praeger Publishing, 1974.
*In thousands of metric tons; all years but 1970 on fiscal-year basis.
†Includes aid under Titles I and IV in previous legislation.
‡Estimate.

United Nations Fund for Population Activities reports increasing requests for population programs assistance.

AID spent $112 million on population programs (of a world total of $200 million spent by United Nations agencies, private groups, and individual countries) in 1974. Both United States and total world expenditures for population programs have increased nearly 50% since then, but the United States still provides the greatest share, and an enthusiastic reception for these programs is hardly found, for cultural and other reasons. United States officials are often frustrated by what they interpret as the developing nations' contradictory position: family planning is guarded as an internal policy matter; at the same time, pleas for more food are made.

More food aid. The United States has been sending more food to developing countries. Under the 1954 Food for Peace Program (P.L. 480), American food surpluses have been sold (under Title 1) and given away as emergency aid (under Title 2). The table summarizes activity under this program for the 1960–1974 period.

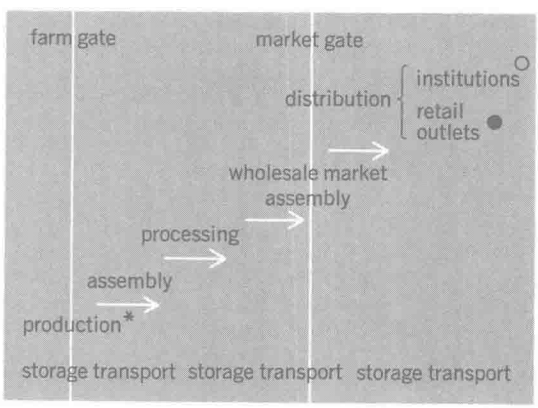
Even if requests for more food are a typical reaction of the developing countries, the situation in the United States makes that solution impractical, if not impossible. Because of the energy crisis, the United States agricultural system is facing problems in the very areas responsible for its earlier success.

Fossil fuels—for planting, spraying, fertilizing, and harvesting—are the key to United States food production. Under current circumstances, some see this now as the weakest link in that production system. Many present-day food products require fossil fuels for production. Recently, several oil companies have begun experimental programs to produce single-cell protein directly from fossil fuels, by-passing the fields altogether. Irrigation is another large energy consumer. One comparison indicates that the United States requires eight times as much water as India to produce the daily food for one person.

In any event, more considered forms of assistance are necessary. More-developed country development assistance, for example, in the form of food aid, can have unintended consequences if less-developed country self-help programs are defeated. A study by the U.S. General Accounting Office has found that the food aid program has a large component of farm surplus disposal to it, making it an adjunct to the farm price-support programs rather than an emergency food supply program. This may change, depending upon domestic politics. Aid to less-developed countries must move away from large projects—providing "747" jets and steel mills—toward systematically increasing the productivity of the food supply system, beginning on the farms where most of the world's people still live. If this were to happen, the process of income redistribution would be more likely to occur, as the poorest people would then get an opportunity to become more productive; but this is a joint political decision of the more- and less-developed countries.

Import more food. Population growth in the developing world accounts for 70% of the increase in the demand for the food supply. The remaining 30% is due to higher incomes; that is, as people become more affluent they "upgrade" their food intake. (In the developed countries this population-affluence ratio is 55:45.) In the future the share of the demand for food in less-developed countries due to population pressures is likely to increase. United Nations population projections indicate that 90% of the increase in the world population will occur in the developing countries.

In slightly less than one-half of the less-de-



key:

* about 50% retained on typically small (1-10 hectare) farms, where 80% of world's food is grown and 70% of world's people live; only surplus goes beyond the farm gate—of which 20-50% is food loss

○ hospitals, schools, industrial facilities, transportation carriers, facilities for law enforcement, welfare, tourism, national defense, and disaster relief

● 80-85% of total human food consumed

Fig. 9. Simplified representation of food production and food distribution in a developing nation. (*From D. N. Ross, Partners in Agroeconomic Development, The Conference Board, New York, 1977*)

veloped countries the 1961–1974 food supply increase did not meet the estimated domestic demand. As a result, food imports by developing countries in the 1961–1970 period increased 3.3% yearly and, in the 1971–1974 period, 7.1% yearly. Both price of foodstuffs and the quantity demanded are soaring. In 1955 commercial food imports cost developing countries $996 million; in 1967, $3 billion; in 1972–1973, about $4 billion; and in 1973–1974, $10 billion. Coupled with increased oil-energy prices, the non-oil-producing Fourth World countries have accumulated tremendous balance-of-payments deficits in their international current account—merchandise trade, travel expenditures, and income and investment flows. The Fourth World balance-of-payments deficit in 1973 was $9 billion; by 1975 it had reached $35 billion. The capacity of these poorest nations to cover a deficit, from aid and capital inflows, without running down currency reserves or resorting to heavy borrowings from the World Bank or from international markets, is estimated at only $15 billion. The predictable is happening: massive rescheduling of commercial debt and emergency borrowings from the International Monetary Fund.

Food supply system in less-developed countries. People do not simply want food; they want it at particular places at particular times in certain amounts and in accustomed forms. A food supply "system" involves much more than agriculture, although agriculture is still the starting point, and weather and temperature still make the difference between one year's situation and the next. A food system encompasses the entire commodity flow from initial inputs to the final consumer, and all the participants involved in the production, processing, and marketing of a farm product. It includes farm suppliers, farmers, storage operators, processors, wholesalers, and coordinating institutions, as well as agricultural and nutritional research, agricultural extension services, and nutritional education programs.

A simplified system. Increased food production, by itself, does not automatically result in the improved nutritional status of a nation's population. Products must make their way through the entire food system to people who have enough money to buy them. Figures 9–11 illustrate the developmental and technical complexity of the food supply flow.

Figure 9 shows phases of the food supply. All are critical; if one phase such as assembly breaks down, food loss occurs. It is estimated that, depending upon circumstances and countries, post–farm gate food loss varies from 20% to as high as 50% of the food produced.

Figure 10, illustrates the necessary coordination between government programs and business ventures at the initial phase of the food supply system—in the areas of production credit, management, and better seed quality, for example—and links it to other aspects of development.

Figure 11 illustrates the technical aspects of the processing phase, using soybeans as the example. Processing is the first main "value-added" stage in food product manufacture; it is at this level that new domestic employment is created and new products become available domestically and internationally.

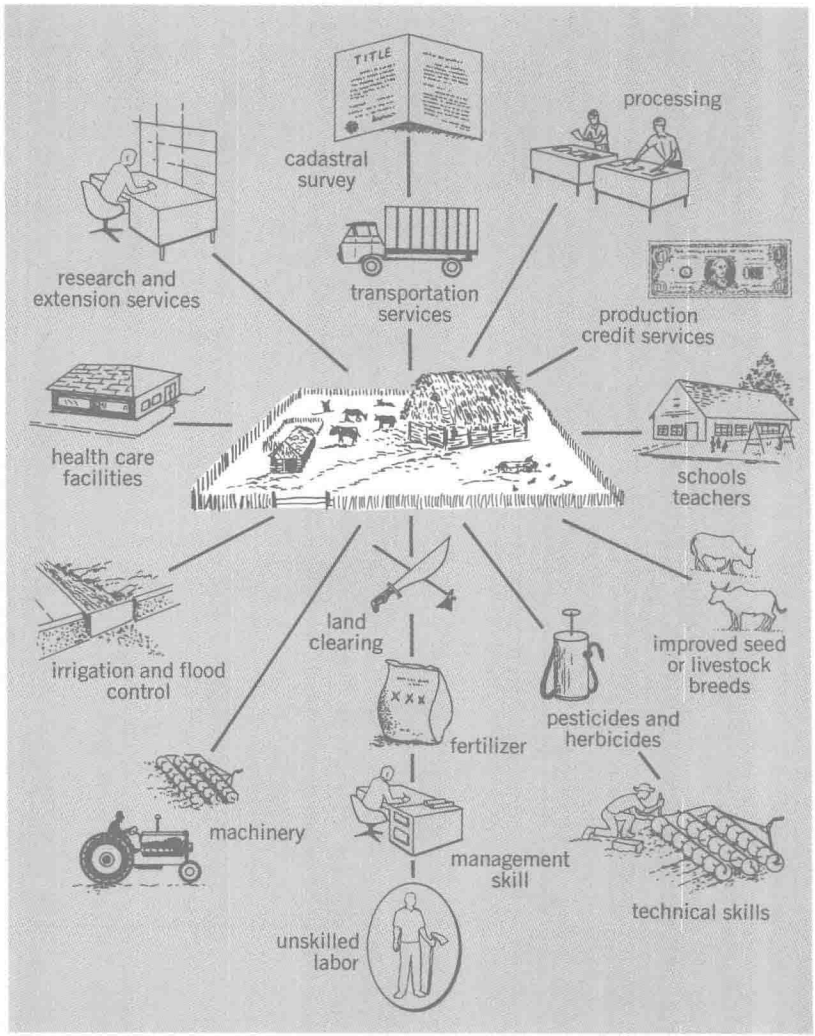


Fig. 10. Production inputs required to create commercial farms to compete in world markets.

Figures 9–11 are intended to illustrate the complexity of the linkage between the food supply flow and the agroeconomic development process. Moreover, most food-related problems are intimately related to, and not distinct from, the development process. Each of the many analyses of the population-food problem may be valid as a part of the whole, yet invalid if, by itself, it purports to explain the problem.

The complex nature of the food problem necessitates the implementation of a coordinated program of action in order to effect a change in the result produced by the food supply system. For example, following the 1965–1966 famine Indian small farmers were pressed by their government to adopt high-yielding varieties of grain and to use fertilizer. The resulting production surplus, however, met with an absence of storage facilities and inadequate marketing channels. Grain prices dropped and many farmers were unable to repay fertilizer loans. The need for complementary institutional roles of government and business is illustrated by this simple yet tragic example.

A government role. Less-developed country policies can affect every aspect of the food supply sys-

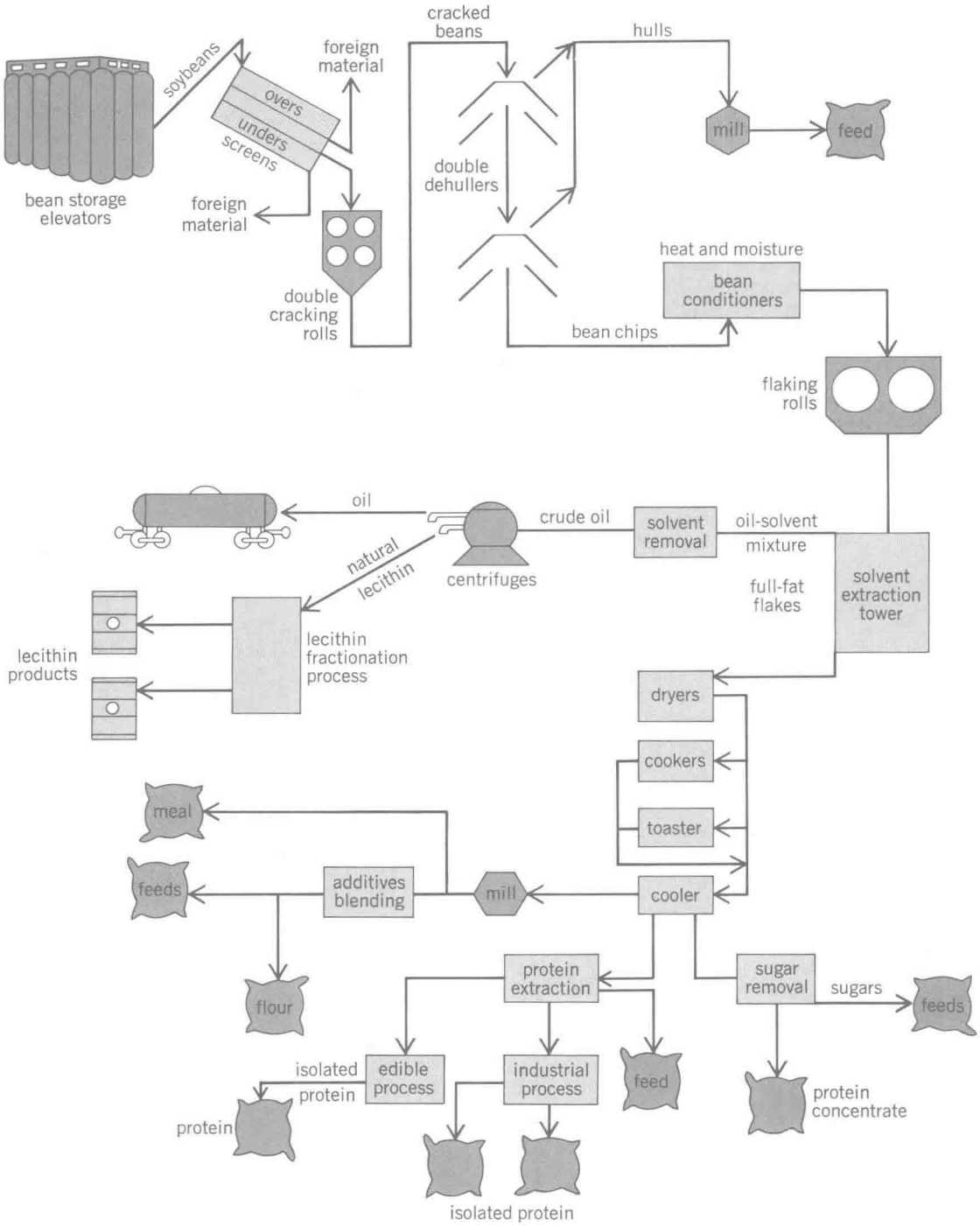


Fig. 11. Technical aspects of modern soybean processing. (*From J. D. Long, From farm gate to dining table: A look at central soya, Bus. Horizons, 19*(5):12–25, *October 1976*)

tem. Yet officials at the World Food Council (the United Nations organization charged at the 1974 World Food Conference in Rome with preventing a forecasted 1985 shortfall of 85 million metric tons of grain) claim there is incredible apathy on the part of both more-developed and less-developed country governments. They claim that nations do not want to change their policies, perhaps because policy-makers are not personally affected by the malnutrition problem. Or, it may be a question of priorities, and less-developed country governments may have decided to improve their country's balance of payments by moving products into international trade channels rather than into local utilization. Much of the current debate on nutrition priorities revolves around the efficacy of this choice of priorities.

Less-developed country policies can impede,

rather than promote, the flow of agricultural commodity production. For example, "cheap urban food" programs usually act as anti-incentives by keeping food commodity prices at low levels, thereby encouraging either cash-crop production (such as cotton, coffee, and tea) or the transfer of human efforts and capital resources away from the rural and agricultural sectors toward the urban and industrial sectors. However, in Argentina a reversal of this cheap food policy has resulted in record grain harvests. Farmers, free of export taxes and some price controls, expanded acreage sown to grain by nearly 10%, increased fertilizer use considerably, and produced for the first time since the 1930s a wheat and oilseed (soybean) surplus that in large measure pulled Argentina out of its chronic trade-deficit position.

Possible more-developed country actions in the face of renewed less-developed country competition for world markets pose nagging questions for the future. The United States now relies heavily on receipts from grain sales to cover mounting expenditures for oil. And a new international spirit of sharing is hardly evident in the reactions of United States consumer interest groups to coffee price increases.

A business role. The primary role of business is the development of a viable operation that creates wage-paying jobs and fosters the process of capital formation within a country. While business considers each venture in relation to the entire food supply system, the focus is on specific ventures. Opportunities to increase efficiency, or reduce waste—and thereby make a profit—may occur at any phase of the system. To illustrate, a "food service" company that operates in a less-developed country environment in which the government's number-one priority is feeding the urban masses to avert political unrest concentrates its efforts on institutional markets: hospitals, schools, and the military. The aim is to reduce waste and to provide nutritionally balanced meals from locally grown foods. Product quality specifications, agreed upon by the company and the government, put pressure on all phases of the food supply system—wholesalers, processors, farmers. The result is better meals, less waste, upgraded facilities, and better-quality products available to local markets.

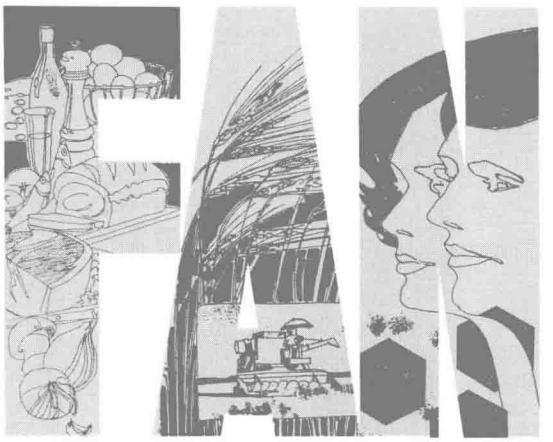
Conclusion. A "doomsayer's" case could be made about the food supply system in less-developed countries, but it would ignore the learning involved in failure and omit the few good examples of systematic, patient and, increasingly, coordinated actions. Some of the gloom may be dispelled by increased sensitivity on the part of developed and less-developed countries, but most of the pessimism will be driven away by a sincere, sustained, environmentally sound, and balanced industrial and agricultural development effort.

CONSEQUENCES OF FAILURE

Achieving a bright long-range future probably will necessitate getting through very troublesome near- and medium-term futures. In the medium term, to 1985, even if less-developed countries' food demands decrease—due to commercial imports, domestic production improvements, and food aid—the number of people suffering from severe protein-calorie malnutrition is projected by the United Nations to increase from about 400 million to nearly 700 million. This is due to the "dilution-effect" that increasing population growth rates have on production increases.

Future-oriented "systems dynamics" groups have become interested in the interrelationships among all the components of the food supply systems. These relationships—usually quantified into numerical variables—are set out in computer-based models. The models are able to project the "results" of various interactions at some long-range future time. In perhaps the best-known prognostication (The Club of Rome's *Limits to Growth*) food production per capita rises to a maximum by about the year 2000 and then drops sharply because of population growth and the rapid depletion of resources (with an attendant population increase), all to the detriment of agriculture. This does not have to happen. The importance of such models is that they enable the cumulative effects of small actions, or inactions, to be seen. In general the studies suggest that real economic growth is essential to the achievement of acceptable and sustainable standards of living for all people. The studies suggest that the nature of economic growth must change and, generally, they underscore the need for political and economic institutions to change as well. In any case, stopping population growth is critical.

The population programs of the 1960s and 1970s appear to be making some headway, but the task of the world's food supply systems in the last quarter of the 20th century is immense. While the specter of Malthus's predictions remains, there is no inexorable process for its materialization. Starvation and malnutrition are not necessary conditions of human existence. What happens depends upon government policies—from population programs to food production incentives—coordinated with business actions, and upon a sustained willingness to address the problem. [DOUGLAS N. ROSS]



CLIMATE AND CROPS

James D. McQuigg

development of formally organized meteorological networks to provide detailed records of weather events (temperature, wind speed and direction, atmospheric pressure, cloud type and amount, humidity, precipitation, and so on) is a very recent occurrence compared with the length of time humans have cultivated crops or managed herds of livestock. There is ample evidence, however, from historical writings and folklore and from anthropological and geological investigations to support the claim that a number of changes have taken place in the Earth's climate since humans first appeared.

Five thousand years of records from China include comments about trees and plants flourishing in certain parts of the country, disappearing for a time, and then reappearing as the temperature and precipitation shifted. For example, at one time rice was grown far north of the present rice region. In England vineyards flourished in areas that long since have become unsuitable. Ancient explorers from Scandinavia established colonies in Greenland, which had a more hospitable climate at the time.

The decadal mean annual temperature graph shown in Fig. 1 was prepared by P. Bergthorsson, using a series of temperature and historical data. While one could argue about the precision of temperature data derived from historical accounts, Bergthorsson's work accurately reflects the magnitude of climatic variability.

While most persons perceive that there have been shifts in climate over the past thousands of years, they tend to regard present-day climate as a "given," to be included in an economic model as a constant. This tendency exists in part because the magnitude of meteorologically induced variability of crop production has been small during a number of the years following World War II, and in part because most people are taught a narrow definition