

World Food Production Potential and Constraints Upon it

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It is useful that these deliberations on world food supplies and trade are held in a year when agricultural production and commodity stocks are large in the United States. We need to be concerned continuously with food supplies, and not just sporadically when there are crop shortfalls in some world regions. Leaders in this nation and other countries seem to go through a frenzy cycle relative to world food problems. The peak of the frenzy cycle comes when crops are poor in some world regions, grain prices increase dramatically in world markets, and large groups of people suffer intensified malnutrition. The trough occurs when grain supplies are large and domestic prices are low. We then turn away from long problems of world food supplies and become more concerned with price supports and restrained production in the United States. Peaks of the frenzy cycle occurred during the early 1950's with the fifth-plate concern, in 1966-67 with **drouth** on the Indian subcontinent, and following 1972 with large crop shortfalls in Russia and parts of Africa and Asia. By the late 1950's, national concern was on land bank and other means of reducing food supplies. Following Secretary Freeman's relaxing of supply controls in 1967, large U.S. production and depressed farm prices in 1968 probably finalized the victory of **Nixon** over Humphrey by a slight margin in the Midwest. And by the fall of 1977, Secretary **Bergland** was already proposing a reduction by 20 per cent in wheat and 10 per cent in feed grain production in the United States.

As long as our concerns follow this oscillating and transitory pattern, we are unlikely to develop sustained long-run solutions to the world's food problems. This cycle itself is one of the restraints on improved world food supplies. Hence, it is useful that institutions conduct conferences such as this to keep the dialogue alive

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even during periods of large domestic production and temporarily relaxed world food problems.

Potential Sources of Increased Production

The assignment given this paper is an analysis of potentials in world food production and the effect of resource, market, and policy restraints upon them which hold world food supplies in check. For an orderly analysis it is useful to first inventory the potential sources of increased food production and then evaluate the restraints. There is basis for optimism for meshing world food supplies and demand over the next 40 years if restraints on both institutions and market relationships are identified and eliminated through appropriate policies. The picture is still not unlike that disclosed in our basic study nearly a decade back [2]. However, appropriate policies, particularly those relating to population growth, must be exercised soon and effectively if the world is not to become enmeshed in a pincer from which it has no ready escape.

Some major means of increasing world food supplies include the following: (a) By increasing yields through improved technologies such as high yielding varieties, crop fertilization, pest control, improved water management, etc., by means of research, technology transfer, and education: As explained later, opportunities for thus increasing yields are generally highest in the developing countries where yields currently are low compared to developed countries. (b) By more intensive use of currently cultivated land, through multiple cropping, intercropping, and related means that more efficiently use available rainfall and solar energy: There is considerable opportunity here, especially with potential development of water supplies and changes in water management, laws, and pricing. The possible gains from this source have been well-illustrated in Taiwan, the Indonesia intercropping system, and research at the International Rice Research Institute. Generally, the less developed countries have climates **with long** or year-around growing seasons, conforming with multiple cropping possibilities and flexibility in cropping seasons. (c) By bringing uncultivated land into production: There still are sizable areas evidently that are not under crops and a considerable area devoted to shifting cultivation. Uncultivated land prevails in considerable quantities in the savannahs of South America, the Amazon Basin, large parts of the bush in Africa, and outer islands of Indonesia and Malaysia. It has been estimated [7, 10] that of potentially arable land, only 22 per cent of that in Africa, 11 per cent of that in South America, and about 45 per cent worldwide is now under cultivation. The Wageningen group [6] estimates that whereas 1,406 million hectares currently are in cultivation, some 3,419 million hectares potentially are arable. They estimate that irrigated land could be increased from 200 million to 470 million hectares. Another estimate puts the world's potentially arable land at 9,000 million hectares [8]. While these figures are too optimistic, and use of some fragile lands could cause environmental

deterioration, land is not a scarce resource in all parts of the world or there would be less shifting cultivation. Even the United States has a considerable amount of land that could be brought into grain cropping under sufficient capital investment and under sustained high commodity prices. Estimates suggest that there may be as many as 265 million acres which could be converted to the equivalent of capability Class I-III land, with 150 million acres having good potential for conversion [9]. Capital requirements are, of course, heavy for leveling tropical jungles, controlling second growth, and maintaining soil fertility. Other problems of forest soils, processing facilities, and markets also prevail in some of these locations. FAO estimates [3] that an additional 53 million hectares of new land could be cropped in 10 years at a cost of \$26 billion at monetary values of the early 1970's. Another 46 million hectares could be renovated and improved for \$21 billion and irrigation schemes could be developed on 23 million hectares for \$38 billion in 10 years. These costs would be \$8 billion annually over a 10-year period (under monetary values of early 1970's). While these figures suggest feasible expansion in the arable land base over the future, greatest potential for increased food production is in improved technology and intensification of production on lands already cropped. (d) By saving a greater proportion of crops that are produced: Estimates indicate high losses, especially in less developed countries, to rodents and birds and through spoilage in inadequate silos and granaries. (e) By diverting a greater proportion of grains from livestock consumption to human consumption: This is, of course, a complex and debatable alternative [24]. In general, it implies shifting a greater proportion of the world's grain consumption, from the rich countries where per capita consumption of meat is high, to the poorer countries where per capita direct consumption of grain is high and grain consumed through livestock is low. Since this is a controversial source of increased food availability for the world, policies to implement it are not likely to be initiated soon. It could, of course, be implemented through two extremely different mechanisms. One would be a set of "outright rules" that prevented grain feeding of livestock, except in cases where the procedure allowed a greater conversion of waste forages or other materials into food. Use of this approach is unlikely. The second would be through economic and market institutions. If per capita incomes over the world suddenly could be raised to the level of England, for example, consumers in Asia, Africa, and South America would bid the price of grain to be used as food so high that grain feeding of livestock would take a drastic decline. World grain supplies then would be spread more evenly among consumers worldwide, greater food availability from existing resources would prevail, and population could advance a few more steps — until it finally struck the restraints of a world of grain consumers and vegetarians.

As mentioned previously, the most promising manner for increasing food production likely is through land already in cultivation. The opportunities here are still considerable: The developed market economies produce 60 per cent of the world's grain production on 36 per cent of the world's grain area; the developing countries

produce only 40 per cent of the world's grain supply on the other 64 per cent of the area [21]. The capability of the world to produce more food also is apparent from comparison of yield trends in developed and developing countries. In the period 1934-38, grain yields averaged 1.15 tons per hectare in developed countries and 1.14 tons in developing countries — practically the same yield. In the period 1973-75, yields in the developed countries averaged 3.0 tons while the developing countries had 1.4 tons [16]. Of the industrialized countries, only Japan had significant increases in grain yields in the 19th century. In the last 25 years of that century Japanese grain yields increased from 1.3 tons to 1.9 tons per hectare. Otherwise, most of the yield increase in industrialized countries has occurred in the last 40 years. Before 1940, grain yields in the United States averaged less than 1.5 tons per hectare, but in recent years have been 3.5 tons. There is little reason why developing countries cannot do as well or better than developed countries, particularly since the former are largely in tropical climates with opportunities of multiple cropping while the latter are mostly in temperate climates.

The 1930's was a period in which only a small amount of chemical technology was being used in the agricultures of both developing and developed countries. Improvement in varieties and use of hybrids was modest everywhere, as compared to developments since then. An important reason for these differences in yield trends has been investment in agricultural research and education. This was the basis for the early Japanese gain in land productivity [13], and especially for the United States in the last four decades.

With yields in the developing countries less than half those in developed nations on an equal cereal acreage, the physical potential for increasing world food supplies is quite obvious. Water resources now used for irrigation over much of the developing world are deployed inefficiently. Improving the physical, legal, and economic conditions surrounding water use could add a considerable increment to food supplies. Further development of water resources also could add to food supplies. Land reclamation, to bring a greater area under cultivation, could proceed a long ways in increasing food supplies. How far it *should* proceed depends on the supply price which the world's consumers are willing to pay for food and the trade-offs implied in producing more food for more people relative to other investment alternatives on behalf of humanity. Certainly much more food could be produced on land not now cropped if humanity were able to make the needed investments and to drive the supply price of food high enough. It will probably do so if per capita incomes and population in the developing countries increase sufficiently and simultaneously. Under certain conditions of growth, however, developing countries are going to have to face more directly the trade-offs among major competing alternatives such as (a) continued rapid population growth, investment in land reclamation, and high marginal supply prices for food, or (b) reduced population growth, greater investment in education, other human capital, housing, health facilities, etc.

Aggregate Production Possibilities

A number of studies have projected world food production into the future. The Wageningen group [6] is highly optimistic for the long run and estimate the absolute maximum potential food production to be almost 40 times greater than that of current production. Our own projections [2] while less optimistic also provide favorable possibilities for the next 30 years, a period in which the developing countries could begin to "get their house in order" for reducing population growth rates. These data, estimated separately on a country-by-country basis then aggregated, cover the world except for China, North Vietnam, and minor areas. (In a set of estimates including China and both its supply and demand potentials, the possibilities under the several combinations of alternatives are qualitatively the same — deficits being accentuated under high demand variants and balances remaining relatively favorable under high land bounds and restrained population growth.) We present data for cereals only since outcomes for other products are similar under each set of alternative futures. Estimates allow food consumption cereals to grow with income and population either directly through human consumption or indirectly through livestock consumption.

Table 1

ESTIMATED WORLD FOOD DEFICIT (–) OR SURPLUS OF PRODUCTION (+) OVER DEMAND OR REQUIREMENTS, UNDER ALTERNATIVES IN FOOD DEMAND AND SUPPLY VARIABLES FOR YEAR 2000 (1 000 METRIC TONS)*

Population Level	Constant Per Capita Incomes	Historical Rate of Growth in Per Capita Incomes
Low Land Bounds		
Low	302,191	177,069
Medium	158,248	– 22,989
High	43,193	– 132,801
High Land Bounds		
Low	322,988	137,876
Medium	179,055	– 2,182
High	64,000	– 11,914

*Derived from tables 10.09-10.20 of Leroy L. Blakeslee, Earl O. Heady, and Charles F. Framingham, *World Food Production, Demand and Trade*, Iowa State University Press, Ames, 1973.

Under the most unfavorable circumstances of high population and income growth and low land bounds, world cereal production would fall short of con-

sumption requirements or demand possibilities by 132.8 million metric tons in the year 2000.' With low population and income growth and high land bounds, our projections even suggest that a world surplus of food commodities could prevail. With only medium population growth, a controversial upward trend in per capita food consumption and agricultural productivity and cropping of favorable available land, projected world food requirements could approximate (only slightly exceed) world production possibilities. The recent estimates by Rojko *et al.* conform generally with these projections [21].

Not all estimates of future supply-demand balances are so optimistic. The Club of Rome [19] presents a dark outlook under any scenario. The IFPRI [15] estimates for developing market economy countries alone indicate a 10 per cent gap between production and "needed food consumption" within these countries in 1990 if per capita consumption levels remain at 1975 levels. The gap within these countries between production and demand in 1990, with income growth at high levels, is estimated at 21 per cent. This gap would arise under trend increases in production and does not suppose any step-up in converting land not currently cropped to arable conditions, accentuating the rate of developing or improving irrigation, in multiple cropping, or technological improvements. The deficits stated refer to those within the developing market economy countries. They represent projections of what may happen under ongoing production and population trends. They are not a prediction of what will happen. The projected deficits also could, for example, be offset partly or entirely by imports by surplus-producing developed countries.

Restraints in Attaining Production Potential

To be optimistic with respect to *how* much food can be produced is not being optimistic with respect to *how* much will be produced. How much will be produced from available arable land and water resources depends on the implementation of appropriate policies that impinge on food production in the developing countries. To a large extent, augmentation of food supplies in them does not involve new or mysterious processes. It requires processes which are already known in executing agricultural research, in investing in land and improved water development, in keeping agricultural production profitable, in augmenting input supplies and related steps. But administrators and politicians in developing countries must be serious in applying appropriate policies so that these processes are executed.

The task of selecting and implementing appropriate policies should be easier in the future than in the past. And some important progress was made in recent decades. Over the period 1960-75, cereal production in the developing countries increased at the rate of 3 per cent per year, considerably above the population rate of 2.5 per cent. In the period 1960-66 some 56 per cent of the increase came from expansion of land area; during 1967-75 nearly 70 per cent came from yield increases.

With the potentials summarized earlier, it would seem that as much or more could be accomplished in the next two decades. Developing countries are better supplied with trained and experienced manpower and administrators than they were in the 1960's when most were only a few years detached from colonial administration. Of course, fluctuating political conditions and remaining restraints in the number of trained planners and administrators can serve as an important barrier in many.

To be optimistic on the ability of the world to produce enough food to keep up with population increases and eliminate a good share of the existing malnutrition over the next 30 years does not solve the longer run problem of high birth rates and population growth over the next 100 years. But the world does have a period of 30-40 years in which to gear up programs which reduce birth rates. The variables involved are complex and they must be tackled with greater vigor immediately if population and food demand are to be reasonably restrained against food supplies in the long run. They include not only the conventional educational and technical means for reducing birth rates but also they involve increased per capita income, improving the worth of women's time, and developing social security or old-age pension programs. An improvement in the value of woman's time through education, employment opportunities, and economic and social participation is a necessary step in reducing birth rate. The opportunity cost of a woman's time must become so great that she cannot afford to produce so many children. Similarly, social security programs must be developed in all countries in order that parents do not have to raise so many children to support them in old age.

During the 30-40 years which developing countries have to attain these conditions on the side of population and demand, physical restraints are not likely to serve as the ultimate limits on food supplies. More nearly, the binding restraints are those of economic policies which prevent available physical resources from being sufficiently developed, which depress incentives to use more purchased inputs, and interfere with trade which would better exploit international comparative advantage in food production.

INVESTMENTS IN RESEARCH, COMMUNICATION, AND PERSONNEL

The earlier Japanese advances and the yield gains of the United States over recent decades resulted from investments in research whose results were then communicated effectively to farmers. At earlier times, this investment in research was made mainly by the public. In recent times, as agriculture has become more capitalized, the private sector has been equally important in researching and communicating new production possibilities to farmers. In developing countries, however, this investment remains largely a function of government enterprise. Its importance was reflected in the "green revolution" composed of improved wheat varieties, fertilizers, pesticides, and irrigation which rapidly increased wheat pro-

duction in regions such as the Punjab in India and parts of Pakistan but which has not yet swept the world.

An increase in expenditures on agricultural research is necessary if the production potential on presently cultivated lands is to be attained. The gap cannot be completely filled by the international research institutes funded by donor nations since much adaptive research is site specific. The low income countries invest only 25-40 per cent as much on research, relative to the value of production, as do the developed high income countries [4]. The international institutes can contribute greatly in more basic work such as developing genetic materials. While they provide a foundation for further improvement, developments such as these do not substitute for the adaptive research and the development of practices which are complementary with the local environment. Also, there is the possibility that existence of the international centers may lead developing countries to rely too heavily on them and neglect their national research programs.

Restraints in research stem not alone from the magnitude of investments. Related problems are those of the organization of research, the supply of trained personnel, and salary levels. While a few developing countries have a fairly large number of persons trained to the Ph.D. level, lack of trained manpower is the dominating restraint in a greater number. It is, of course, a restraint which can be overcome in the next decade if developing and donor countries are willing to make the investment. One estimate [19] indicates that 30,000 new university graduates per year are required for a sufficient agricultural research and extension system to promote agricultural development at reasonable rates. But even if the investment is made, research institutes must be able to hold newly trained personnel. Salary levels in research institutes and universities in the majority of developing countries are too low to hold young scientists and they soon move into administrative, private sector, or international employment. Other problems of research organization also exist including seniority and bureaucratic systems which discourage newly trained personnel, the concentration of research on one or two major cereals, and industrial crops with little emphasis on root, protein, and similar foods.

Hopefully, the supply of manpower, as compared to two decades back, is now large enough that a good number of developing countries can begin to pursue aggressive agricultural research programs. An event which should have spurred them to do so was the relative shortages and high prices of food during the mid-1970's. There is little evidence, however, that any quantum leaps have been made either in the magnitude of investment in or organization of agricultural research.

PRICING POLICIES

National pricing policies also have served as a restraint on cultivator investments and greater food supplies. Frequently, pricing policies have a main orientation to consumers. By keeping the real price of staple foods at a low level, they

bring gain to consumers in the short run. But in doing so they may disfavor the consumer in the long run as they make farming and innovation less profitable and discourage greater food production. A number of countries have used domestic pricing policies causing agricultural commodities to be undervalued. It has been estimated that Indian government policies since 1963 have caused rice to be underpriced, relative to world markets, around 50 per cent [22, 26]. Thailand has used an export tax on rice (termed a rice premium locally) which also has the effect of drawing down the price to farmers. With a more elastic export demand for Thai rice, the tax dampens exports and dumps a greater supply in the domestic market where demand is less elastic. Again, urban consumers gain at the expense of farmers and incentives to innovate, use more capital, and improve yields is lessened. In some countries of the Middle East and in Peru, import subsidies on food have similar effects. While consumers gain in lower food prices, this impact dampens farmers' incentives to produce. With farmers required to deliver quotas of wheat, corn, rice, and cotton to government at low controlled prices, Egyptian farmers have shifted more resources to fruits, vegetables, and livestock which do not have price controls. Food availability to the total population thus is less than it otherwise would be and balance of payments is worsened (as export earnings from cotton decline and greater wheat imports are required).

Urban consumers generally are more vocal and have much greater political clout than do the unorganized cultivators in developing countries. They are, of course, important to government administrators and politicians who wish to maintain political stability. Still, means do exist whereby staple food commodities can be priced favorably for consumers without creating disincentives for farmers. A food stamp system which allows consumption to be subsidized through government redemption of coupons is one [25].

Modernization of agriculture and improvement of yields on currently cultivated land is accomplished with biological inputs such as improved seed varieties, fertilizer, and pesticides. Profitability of farming and incentive to innovate also can be affected by policies which cause these inputs to be highly priced relative to commodities. Historically, fertilizer prices have been much higher in developing countries than in developed countries. Even now they are high in countries such as Thailand, Philippines, and Indonesia.

Much has been learned about the responsiveness of cultivators in developing countries to price over the last two decades [27]. That even small farms with illiterate operators respond positively to favorable commodity/input price ratios is well quantified. Hopefully, policy makers and administrators will heed this information and refrain from programs which cause farm commodities to be undervalued and inputs to be overpriced in the future.

There is some indication that a number of countries which underpriced agricultural commodities in the past have moved or are moving towards more useful pricing policies. Hopefully, economic evidence of the past and better trained and

experienced policy administrators can be combined to provide pricing regimes which will spur agricultural improvement in the developing countries. Minimally, domestic prices need to be allowed to rise to world levels, with minimum levels guaranteed so that risk and uncertainty do not restrain farmers' decisions. While in the past they have had a record mainly of bringing gain to larger farmers, input subsidies can be used to provide an initial push in adoption of new technologies by both large and small farmers. Means mentioned previously can handle welfare problems of low income urban consumers.

INTERNATIONAL POLICIES AND TRADE

International programs with a similar effect are an extension of domestic policies which cause farm commodities to be underpriced. One program in this category is the limitation of exports until domestic consumption needs are met. The result is lower prices which serve as a disincentive for farm production. Programs which cause a country's currency to be overvalued can serve similarly in choking down on exports and domestic commodity prices. Lopez [18] estimated that export restrictions and overvalued exchange rates in Brazil lowered agricultural prices by 10 per cent, agricultural employment by 18 per cent, and use of capital by 27 per cent.

In previous times the United States participated in depressing prices in developing countries through its massive P.L. 480 food aid program whose dominant purpose was to improve domestic prices by moving surplus supplies out of U.S. markets. Hertford et al. [14] show that between 1953 and 1973, during a period of large imports and P.L. 480 grain from the United States, wheat acreage in Colombia fell sharply and investment in wheat research was cut in half. Parallel observations have been made for other countries and times [23, 25, 29]. While producers in developing countries have had respite from U.S. surplus disposal programs in recent years, the current complaint over commodity surpluses and the press for parity could again cause U.S. farm commodities to be overpriced, the accumulation of large stocks, and the implementation of an international food aid program to relieve domestic markets. Ongoing developments closely parallel those of the 1950's and 1960's which gave rise to mammoth U.S. exports under public assistance.

Just as developing countries have tended to undervalue agriculture through low commodity prices favoring consumers, other major developed countries have overvalued agricultural commodities by pushing prices far above world market levels. In addition to the United States prior to 1973, and perhaps starting again in 1977, Japan has done so with rice and the Common Market countries (especially France) with other grains. Levies applied in the latter countries have restrained imports and given high internal grain prices. van Stolk and Johnson estimate that as little as 20 per cent of world grain production moves in markets geared to world

prices [17, 28]. The remaining 80 per cent is marketed within boundaries of countries and world regions which prevent it from responding to international price signals. With international prices held too high in developed countries **and** too low in developing countries, surpluses are the result in the former and a slow transformation of agriculture is the result in the latter. Also, internal price stability is attained by creating great world **market** instability.

Indirectly, too, all policies which dampen trade of developed countries with developing countries restrain development of the latter. An important limitation in most developing countries is foreign exchange. Whether lack of foreign exchange directly limits capital goods imports for industrial or agricultural uses, the effect is generally the same in restraining development. Some improvements for agriculture depend directly on imported capital goods and technology (e.g., chemical plants, fertilizers, etc.). In other cases, if foreign exchange is not available for industrial goods, more of the domestic budget may be shifted from agriculture to the industrial sector.

CAPITAL AND MANPOWER RESTRAINTS

While perhaps not dominant, limited capital also is a restraint to the further development of world food supplies. Combined with decision making under uncertainty, it especially serves as a restraint in adoption of improved technology by small-scale cultivators. It need not do so in the long run, however, if credit policies are adapted to serve this strata of farmers as well as they do larger farmers in developing countries. If the sole criterion were one of food production, it may not have been unfortunate that the larger farmers of developing countries who produce mainly for the market have been the main beneficiaries of institutional credit systems, subsidized inputs, and publicly supplied technologies in the past [5]. Still, the vast majority of farmers in developing countries are small and their existence is important both in terms of their welfare equity goals and food production. (They dominate the populations of most poor countries.)

Capital is a major restraint in the clearing and leveling of land, in improving water distribution, and developing large new **irrigation** systems. In large areas which might be reclaimed for crops, sizable investment in roads and infrastructure would be necessary. Lack of these public investments restricts private investment in land reclamation in many cases. Lack of profitability or price instability may be a major **restraint** in reclaiming the remaining land area which could be converted to crops. A large amount of this land will be brought into cultivation when per capita incomes and food demand drive prices to sufficiently high levels for a sustained period of time. U.S. farmers had 12 per cent more land in crop production in 1977 than in 1972. Had soybeans remained at \$12 and corn and wheat at \$5 for a decade, farmers would have plowed up and cropped many more of the 150-265 million acres of potential Class I-II cropland. Hence, the constraint on

this conversion might be considered to be price level, with equal application to other countries. With grains at their 1973-75 real levels for 30 years, great quantities of soybeans would be flushed out of Brazil from land not now in crops. Similar developments would take place in cereal and palm oil production elsewhere over the world. Part of this would come from private investment. The large private holders of capital in developing countries reside in cities and are alert investors. Many own land cultivated by tenants or relatives and will invest further in **agriculture whenever** profitability becomes apparent. Governments evidently tend to initiate irrigation projects especially in periods when food prices are high [13]. Hence, while the FAO's estimate [3] that 122 million hectares could be cleared and improved for \$75 billion over 10 years may seem large, it will seem less so should grain and food prices rise to high levels over sustained periods of time. To the extent that these conversions are feasible, restraint to their implementation rests importantly on prices and profitability.

It is possible that capital availability has been less a restraint on agricultural productivity than the allocative patterns used for its investment. Only 10 per cent of international aid funds have gone into agriculture. A disproportionate amount has gone into industry and perhaps even some aspects of education. Even of capital allocated to agriculture, some claim that it has been misallocated, especially for land infrastructure development [1]. Supposedly, the personnel who plan major public projects have engineering biases which directs investment into capital intensive systems which prove to be inefficient in labor surplus countries and frequently "never get off the ground." Political and management considerations also may bend capital investment towards industrialization and urban purposes. The great majority of highly educated persons in developing countries are seldom associated with agriculture and are prone to discount the importance of the sector. While emphasis on agriculture fluctuates with crop shortfalls, and high food prices, few countries man a sustained national priority for agricultural development.

Although it is not readily quantified, management is posed as a more binding constraint than capital in limiting the rate and extent of agricultural development experienced in the past. The lack of sufficiently able and experienced management personnel causes inappropriate allocations of capital investments, and inefficient execution of projects once they are initiated. Examples commonly cited include large-scale public irrigation investments which lack efficient tertiary canals and distribution systems for water. This restraint need not, of course, prevail in the long run. Most developing countries have more trained personnel than in the 1940's. And further investments in human capital for these purposes can and should be made. However, the problem currently is crucial in some countries.

EQUITY CONSIDERATIONS

During most of the last 35 years, larger farmers in developing countries have been the major beneficiaries of government supplied credit, subsidized inputs, and

new technology. Developmental programs have been geared more to them than to small farmers. While small farms (under five hectares) occupy only 20 per cent of the land area, they represent 80 per cent of the land holdings in developing countries. In addition to large farm operators, the urban population also has been a major beneficiary in the sense that more food was available or that it was available at a lower real price. The smaller subsistence or semi-subsistent farmers who did not swing rapidly into advanced technology generally gained little through the market or in reduced real prices for grain.

If agricultural development had a single goal of producing only more food, with a zero weight on all other goals of development; it would be entirely appropriate to emphasize large farmers and neglect small farmers. Improvements can be made quicker and more readily with fewer extension and distribution personnel under this emphasis. However, urban people who are the focus of this emphasis are not the only poor and hungry groups in developing countries. Generally, the small farm population is the dominate proportion of the national population and has right to claims in equity.

Increasingly, development policies have come to recognize this need in multi-goal programs. The rate at which food production can increase may be less in the short run as sufficient weight is given to equity and the gearing of programs to its attainment.

While greater food production can be restrained partially by equity considerations in the short run, this need not be a major restraint over the long run. For example, a policy which allows grain prices to move to world levels while consumption by the poor is subsidized through a food stamp (coupon) plan (or "fair price" food stores for the poor) need not provide gain to the urban poor at the expense of farmers [25].

ENVIRONMENTAL RESTRAINTS

Reference has been made to the world's potential arable land. Much of it is not now cropped because of unfavorable environmental conditions, including limited moisture and soil deficiencies. Before the very large area projected by Clark [8] and Buringh *et al.* [6] could be fully converted to cropland, land would need to come from pasture, forests, and jungle uses. Some of these lands are surrounded by fragile circumstances. Bene *et al.* [19] indicate that a large amount of the humid tropical forest might be transformed into unproductive wetland in the next 25 years and the savannas increasingly into African desert. Overgrazing and misuse of semi-arid lands has caused the creation of deserts and erased populations in previous centuries.

Environmental conditions will restrain cultivation and intensive grazing of lands until conditions and technologies are found which can remove the negative environmental impacts. These conditions may require the international manage-

ment and allocation of water and grazing, particularly the diversion and control of water at the headwaters of rivers.

WATER MANAGEMENT

While the FAO estimates indicate another 23 million hectares of land could feasibly be irrigated by 1985, perhaps equally important in food potential is improved water management systems for land already under irrigation. Historic rights, customs, politics, and cultural conditions are barriers to allocations based on the marginal value productivity of water in all countries. Even in the United States, greater production could be forthcoming from given surface supplies if water allocation was broken from its pattern of historic rights and was allowed to move where its marginal productivity is greatest. Existing conditions surrounding water use cause investments in distribution systems to be minimized. Farmers at the head of the main canal receive too much and those at the end have too little water. Supplies are certain for some and undependable for others. Even international development agencies invest in systems with sufficient primary and secondary canals but with inefficient tertiary canals and onfarm distribution systems.

Ultimate Restraint

The restraints on world food production, I have been discussing, are not insurmountable. Prospects are that we can push forward sufficiently on the food supply front to take care of population and demand growth over the next 30-50 years. The world is not necessarily faced with calamity in the short run, but this is only true if the politicians and administrators of selected developing countries enact agricultural, development, and trade policies which hurry and guarantee adequate food supplies. Over the longer run, however, praises or blame for these same politicians and administrators will rest on their actions in initiating and implementing appropriate population policies. In the "pain and joy" of humans, I doubt that a dictator who lines healthy people against a wall is less kind and humanitarian than country politicians and administrators who allow high birth rates to prevail so that many millions are born into poverty and malnutrition and a life of suffering, tension, and frustration which is perhaps more **cruel** and miserable than death. The lack of adequate birth control technologies is not a sufficient excuse for nonattainment. Hungary and other countries have near zero population growth with present techniques. Needed immediately and on a much more intensive basis are larger and more effective communication programs to bring sufficient awareness of birth control alternatives to all of the population; larger public investments to provide the staffs, personnel, and administrative facilities to accomplish the task; effective economic incentives either in the cost of the techniques or in the return for their application; and actual sincerity and concern for future generations, to stir the present

generation of public officials into action. Of course, the ultimate goal is economic growth and per capita incomes at levels which cause families to exert their own initiative. Perhaps one threshold level is attained when the level of affluence of children cause them to draw on family income more heavily as consumers than they contribute to it as resources. But the world can hardly wait for this threshold level to be attained in all countries. The politicians and officials of these countries must speed effective public population policies. Whether the citizens of their countries live in misery at food subsistence levels in a half century will depend on the actions they take in the next two decades. Leaders of developed countries can provide encouragement through technical and financial assistances, but success or failure depends mainly on the leaders and citizenry of developing countries.

Note

1/We use the term demand possibilities since the quantities are not based on a projection of market equilibrium. In reality commodity price flexibilities would cause reduced consumption to be equated with supply at higher prices under some circumstances, etc.

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