USING SYSTEMS ANALYSIS TO SOLVE THE WORLD FOOD PROBLEM 1/

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Few subjects suffer as much from conceptual and semantic difficulties as does systems analysis. The same, incidentally, can be said of the world food problem. The term "systems analysis" will be used in this paper in its broadest possible sense -- viewing the problem in terms of all relevant variables.

With so many conceptions of systems analysis in use I would like to clarify my own with a definition used by E. S. Quade of the Rand Corporation:

> A systems analysis is an analytic study designed to help a decision maker identify a preferred choice among possible alternatives. It is characterized by a systematic and rational approach, with assumptions made explicit, objectives and criteria clearly defined, and alternative courses of action compared in the light of their possible consequences. An effort is made to use quantitative methods but computers are not essential. What is essential is a model that enables expert intuition and judgment to be applied efficiently. 2/

1/ Several of my associates in the International Agricultural Development Service have contributed to the thinking reflected in this paper, but most notably Dana G. Dalrymple and I. M. Destler.

2/ E. S. Quade, Systems Analysis Techniques for Planning - Programming-Budgeting, The Rand Corporation, Santa Monica, 1966, p.28.

The systems method is, above all else, a way of thinking, a way of approaching a problem. The degree of success in its use is related both to the quantity and quality of information available and to the judgment and intuition of the decision maker using it.

Some authorities are not optimistic over the prospects for using systems analysis in the international area. Professor Thomas C. Schelling in recent testimony before a Congressional committee stated:

> And I should like to see the Department of State enjoy the benefits of modern analytical techniques of the kind that Secretary (Alain) Enthoven has brought to the Department of Defense, as well as other kinds. But I cannot -- I wish I could, but I cannot -- declare with any confidence that this can be done. 3/

Though skepticism is justified in applying systems analysis to our entire international involvement, prospects for applying it to the world food problem are perhaps brighter than Professor Schelling's statement indicates. We are not yet extensively applying systems analysis to the food problem; but we are increasingly using the basic principles of systems analysis as we identify and evaluate alternative uses of our resources.

Consider how our approach has evolved in recent years. In the mid-fifties the food issue was seen mainly as a problem of moving vast grain surpluses from the United States to countries in need. By the mid-sixties it was clear that such shipments provided no lasting solution. The transfer of our surplus food production capacity from grain in storage to idled cropland, together with the decline in per capita

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3/ Thomas C. Schelling, "PPBS and Foreign Affairs", Planning - Programming - Budgeting, United States Senate, Committee on Government Operations, 1968, p. 9.

food production in the less developed world, turned our attention to encouraging agricultural development within these countries. Still more recently we have recognized the population side of the equation as a variable which can be influenced as we seek a more acceptable balance between food and people. AID funds for family planning climbed from virtually nothing two years ago to $35 million this year.

Our approach today is much more sophisticated than it was say a decade ago. At that time we relied heavily on the disposition of our grain surpluses to solve the food problem in the less developed countries. Today we rely on food aid to buy time while we help developing countries both expand their own food producing capability and bring their population growth under control. We are seeing this year, not entirely by coincidence, the beginnings of an agricultural revolution in Asia, with high yielding seeds and increased fertilizer use bringing about remarkable production increases.

Identifying Some Alternatives

This does not imply, of course, that we have developed a comprehensive, all-inclusive model with numerous quantified variables and coefficients with which to identify and analyze all the alternatives. We do, however, have some rudimentary cost-benefit data for some of the major activities and inputs, which is influencing our setting of priorities and formulation of policy.

This paper focuses on the world food problem in terms of three selected subsystems and some of the choices they illuminate.

This approach will reflect both the extent to which we are already systematically analyzing the problem, and identify areas in which further analysis is particularly needed. Our central objective is to find more efficient ways to adequately feed the world's people.

The first subsystem is the one in which resources of the U.S. economy are related to, and brought to bear on, the food problem of the less developed countries. Conceptually, it includes resources transferred both bilaterally and multilaterally. For reasons of brevity and because bilateral assistance accounts for most of our total assistance, public and private, I shall concentrate on bilateral aid.

Another system, a generalized one describing various agricultural energy sources within a country, is presented for both modern and traditional agriculture. Technologically, it is perhaps the most interesting.

A third subsystem, describing the relationship between crops, livestock and man, is an elaboration of the second subsystem. It is designed to identify alternative means of meeting requirements for high quality protein at lower cost.

Relating U. S. Resources to the Food Problem

A satisfactory long term solution to the food problem requires both increased food supplies and reduced population growth rates in the less developed countries. U. S. resources, widely used for both

purposes, are transferred both bilaterally and multilaterally, through public and private channels and, when private, through both profit and non-profit institutions.

Increasing the Supply of Food

There are two obvious ways in which we can increase the food supply in a less developed country -- increase food aid or help increase indigenous food production. The latter usually involves the transfer of both capital, either as capital or, more often, in the form of commodities and the transfer of technology either in the form of trained people or equipment. (Figure 1)

Food Aid. The U. S. food aid program expanded steadily during the 1950's then stabilized during the 1960's at about $1.5 billion a year. The 15 million tons of grain, principally wheat, provided under this program feeds the equivalent of 90 million people in the less developed countries -- nearly half the U. S. population. U. S. food aid, provided under the authority of Public Law 480, is administered jointly by the U. S. Department of Agriculture (USDA) and the U. S. Agency for International Development (AID).

The efficiency of the U. S. food assistance program was greatly enhanced by the Food and Agriculture Act of 1965 and the Food for Peace Act of 1966. Together, these two laws gave the Secretary of Agriculture authority to adjust U. S. domestic agricultural production patterns to meet world needs, both commercial and concessional, and to ship any commodities needed in the food aid recipient countries, not just those in surplus.

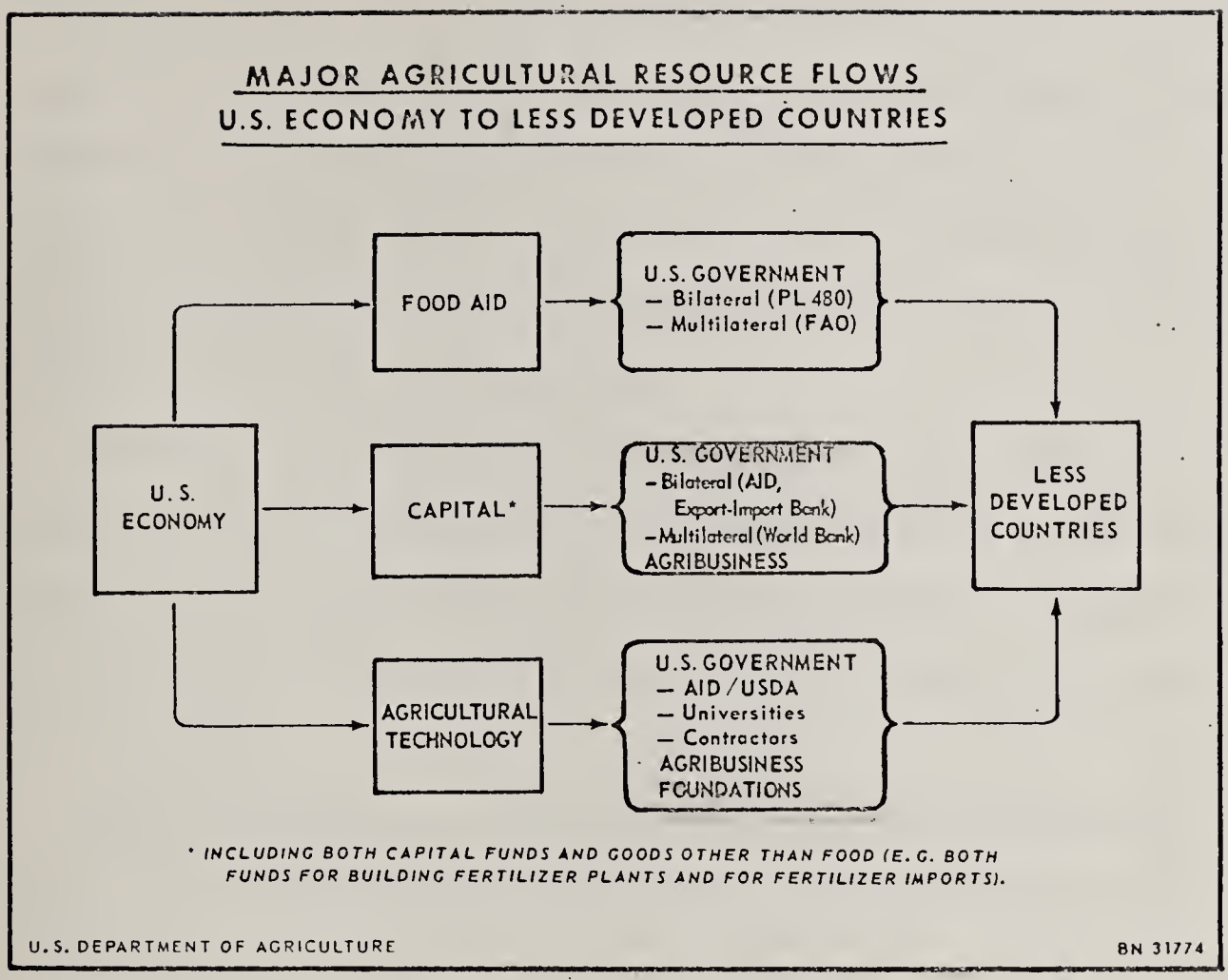
MAJOR AGRICULTURAL RESOURCE FLOWS
U.S. ECONOMY TO LESS DEVELOPED COUNTRIES
U. S. ECONOMY
FOOD AID
CAPITAL*
AGRICULTURAL TECHNOLOGY
U.S. GOVERNMENT
— Bilateral (PL 480)
— Multilateral (FAO)
U. S. GOVERNMENT
- Bilateral (AID, Export-Import Bank)
- Multilateral (World Bank)
AGRIBUSINESS
U.S. GOVERNMENT
— AID / USDA
— Universities
— Contractors
AGRIBUSINESS
FOUNDATIONS
LESS DEVELOPED COUNTRIES
* INCLUDING BOTH CAPITAL FUNDS AND GOODS OTHER THAN FOOD (E. G. BOTH FUNDS FOR BUILDING FERTILIZER PLANTS AND FOR FERTILIZER IMPORTS).
U. S. DEPARTMENT OF AGRICULTURE
BN 31774

Figure 1

In a further attempt to use available resources more efficiently, we have begun to use our food aid program to stimulate more rapid agricultural development in the recipient countries. When a country requests food aid from us now, we examine that country's agricultural development effort and determine what else it should be doing. Once these needs are determined, we proceed to negotiate commitments by the aid receiving government to take action on these matters in exchange for the commodities we provide.

We may, for instance, ask a country to build farm-to-market roads, expand the availability of farm credit or build an additional fertilizer plant. Using food aid to speed agricultural development as well as alleviate hunger multiplies the effectiveness of this form of U. S. assistance.

Capital Assistance. Capital, in the form of funds and commodities, is supplied by both the U. S. Government and agribusiness corporations.

AID-supplied capital assistance to support agricultural development increased from less than $200 million per year in the early 1960's to close to $600 million this year. As a proportion of the total U. S. resource flow, it is climbing sharply. These funds are used largely for importing fertilizer and other inputs from the United States, for irrigation projects, and for agricultural development loans. Food produced with U. S. inputs now substantially augments actual shipments of foodgrains under our food aid program. Fertilizer and food are,

in effect, the same commodity, if adjusted for a one-year time lag.

Reliable data on yearly investments by U. S. agribusiness firms in all the less developed countries are not available. We can, nonetheless make some rough estimates of the contribution of this form of assistance to solving the food problem by focusing on investments in fertilizer plants, which account for a major share of agribusiness capital needs.

Countries in which U. S. firms have built or are building fertilizer plants include South Korea, the Philippines, Taiwan, Colombia, India, Pakistan, Iran, Malaysia, and Brazil. Fertilizer produced in these plants could increase the annual grain producing capability of these countries by 30 million tons, roughly double that now provided under our food assistance programs. Other agribusiness investments, such as farm machinery and pesticides, contribute still further to the food producing capability of the less developed countries.

Because of the central role of agribusiness investment in agricultural development, AID, through its Office of Private Resources, encourages the American agribusiness community to invest even more heavily in the less developed countries through financing pre-investment surveys and the use of investment guarantees.

Agricultural Technology. Agricultural technology is transferred to the less developed countries by the U. S. Government, agribusiness firms, and foundations.

The Federal Government's effort in technological assistance has a long history. Since World War II it has been centered in a number of

agencies, but for several years now, has been located in the Agency for International Development.

AID, in turn, works through a number of channels. First, it has agricultural technicians as part of its own country missions. Secondly, it funds my own agency, the International Agricultural Development Service (IADS) which arranges for and coordinates technical assistance provided by the U. S. Department of Agriculture. Third, it contracts with colleges and universities, most often for work with a counterpart educational establishment. Fourth, it contracts with private consulting firms for specialized assignments.

Agribusiness firms provide technical assistance through their business investments, usually in the form of management and marketing know-how. ESSO, for example, has established 400 agro-service centers in the Philippines which are staffed by trained agronomists. They market both fertilizer from their local fertilizer plant and a complete line of other farm inputs such as pesticides and farm equipment.

Private groups, principally the Rockefeller and Ford Foundations, are the third important channel through which technology is transferred. Their contribution is important not so much because of size but because of strategic value. Foundations have made their relatively small investment count by concentrating it in agricultural research, particularly plant breeding, an activity largely neglected by governments of the less developed countries and by other international assistance programs.

One economist estimates the gross social rate of return on agricultural research and education in the United States at 300 percent.4/

4/ Zvi Griliches, "Research Expenditures, Education, and the Aggregate Agricultural Producation Function", American Economic Review, December 1964, p. 968.

Preliminary evidence indicates a return perhaps several times higher on the expenditures required to develop the new high yielding varieties of wheat in Mexico and rice in the Philippines.

The first such foundation-sponsored research, development of high yielding dwarf wheats in Mexico, enabled Mexico to become self-sufficient in wheat three years ago. These wheats, proving adaptable under a wide range of growing conditions, have been adapted -- and are being multiplied -- in several major food deficit countries, including India, Pakistan, Afghanistan and Turkey.

Success with wheat breeding research in Mexico led the Rockefeller Foundation to join forces with the Ford Foundation to establish the International Rice Research Institute in the Philippines in 1962. In existence only five years, the results of research at IRRI are already having a pronounced impact on rice production in Asia.

The aggregate acreage in non-communist Asia planted to these exciting high yielding varieties of foodgrains totaled 16 million acres this year (1967/68 season), nearly five percent of the area in grain, and is expected to climb to 30 - 40 million acres next year.

Family Planning

The United States is helping solve the food-population problem by assisting the less developed countries with their family planning programs. This activity, like agricultural development, is an area in which government, private industry and the foundations (or foundation-sponsored entities) such as the Population Council, are all engaged.

AID, scarcely involved two years ago, has a $35 million family planning budget this year. This active support is encouraging the densely populated, food short countries to face the realities of uncontrolled population growth.

Recent research suggests that one dollar invested in family planning achieves as much long term economic progress as $100 invested in more conventional developmental activities.5/ As the shortage of physicians and paramedical personnel needed to administer family planning programs is eased, and as the political risk of failing to deal with the problem of excessive population growth begins to exceed that of supporting nationwide family planning programs, this imbalance in investment should be at least partly remedied.

The pressing need to reduce population growth is not new where the systems analyst is concerned. What is new is the realization by the United States and many of the less developed countries that population growth must be slowed -- and a willingness to commit resources to this end. India's family planning budget is $41 million this year, greater than that during the entire third Five Year Plan, 1961-66.

Some areas such as South Korea, Taiwan and Singapore have already substantially reduced their rate of population growth. Some authorities think measurable reduction in Pakistan's rate of population growth may be imminent.

Current efforts to organize family planning efforts will not solve the food problem of the next decade; but hopefully they will bear heavily on the results after that period.

5/ Stephen Enke, "The Economic Aspects of Slowing Population Growth," The Economic Journal, March 1966, p. 56.

India's population, now past the half billion mark, is almost certain to reach three-fourths of a billion, barring any major catastrophe, before it can be stabilized. But successful nationwide family planning efforts launched now may prevent India's population from reaching a billion, a population level which would very seriously hamper India's ability to achieve and maintain food self-sufficiency.

Alternative Energy Sources in Agriculture

The farm sector is a major consumer of energy in both agrarian and industrial societies. In an agrarian society, the greater part of a country's energy supply, most of which is human and animal power, is used to produce food. As a country develops, the quantity of energy consumed in the farm sector increases but the agricultural share of total energy consumption declines.

The amount of energy expended per hectare and yields per hectare are closely associated. Asia, with a yearly energy availability in agriculture of only 0.2 horsepower per hectare, has an average crop yield, principally grain, of 840 kilograms per hectare; the United States, with an energy availability of one horsepower per hectare, achieves an average crop yield of 2,600 kilograms per hectare. The United Kingdom and Japan, both cultivating very intensively, use about two horsepower per hectare and attain yields of more than 5,000 kilograms per hectare.6/

6/ "Manufactured Physical and Biological Inputs," The World Food Problem, The White House, Vol. II, May 1967, pp. 397-398.

At least 0.5 horsepower per hectare are needed to realize most of the production potential of farm land -- beyond that additional energy apparently is used more to save labor and less to further raise yields. The new high yielding varieties of rice and wheat require a far greater energy outlay than did the traditional varieties, particularly in seedbed preparation and irrigation.

Realization of the close relationship between the energy supply and the productivity of cropland is quite recent -- and it has not yet been translated into development plans or strategies.

Traditional agriculture, entirely dependent on raw manpower and animal power, tied four-fifths of a country's population to the land. Only as man has learned to mechanize agriculture and burn fossil fuels in the internal combustion engine has it become possible for a minority to feed the entire population.

Efficiently harnessing modern energy sources has permitted the productivity of agricultural labor to multiply 10, 20 or 30 times. Fossil fuels have provided most of the additional energy.

The most obvious use of these modern power sources has been for mechanization, which can both substitute for and improve on human and animal labor. They are also crucial in providing electricity for irrigation, and in powering the manufacture of fertilizer and other essential inputs.

Developing countries must decide when, where and under what conditions they should seek to replace human and animal power with mechanized equipment. The standard argument that the availability of unemployed labor makes mechanization of low priority may not withstand careful analysis. Labor may be in short supply during

planting and harvest seasons. Also, rapidly spreading practices involving multiple cropping and the use of high yielding seeds often require a speed and a precision in cropping operation which hand labor and draft animals cannot achieve.

In addition to farm tractors one sees growing uses of modern energy as one surveys the Asian landscape, such as trucks hauling fertilizer to rural areas and grain to market, and tubewells with electric powered pumps.

Besides determining how available energy sources can be most productively applied to agriculture, less developed countries must also make hard choices concerning which energy sources to develop for the future. The traditional alternatives are fossil fuels and hydroelectric power. More recently nuclear energy has become a serious competitor.

Low cost electrical power generated by nuclear reactors may become particularly attractive in those countries, such as India, heavily dependent on petroleum imports. Less developed countries must have strategies in mind to guide allocation of budget resources, to formulate policies influencing the use of private resources and to attract the necessary external resources, private and public. Estimates of the relative costs of fossil fuel and nuclear reactors as future sources of power, for example, should be influencing current decisions on issuing licenses for petroleum refineries or initiating publicly funded research.

Food from Petroleum

More recent technological advances indicate it may be feasible to use our dominant energy source, petroleum, to produce food directly.

An exotic food producing technology now evolving is the use of petroleum hydrocarbons as a feedstock for producing edible single cell organisms, such as yeast.

Several large international petroleum companies are funding extensive research and development programs designed to use petroleum or petroleum products to produce both animal feed and human food. Should this effort prove successful, it could have far reaching implications for conventional agriculture. When discussing a country's food producing capability, we may someday refer to population/petroleum ratios as well as population/land ratios. Within Latin America, for example, Venezuela, with its vast oil reserves, could become Argentina's principal competitor as an exporter of feedstuffs and foodstuffs.

With the decision by British Petroleum to begin construction of such a plant in France this year, designed to produce 16,000 tons of protein yearly when it comes on stream in 1970, this technology moves off the drawing board.

Fertilizing the Rumen

The use of urea, a nitrogenous compound initially derived principally from naptha or natural gas and widely used as fertilizer, has gained wide acceptance as a livestock (ruminant only) feeding supplement in the United States. (Figure 2) When combined with high starch rations, it permits microorganisms in the rumen of cattle and other ruminants to synthesize much of the needed protein. Urea thus substitutes for high protein livestock feedstuffs such as soybean oil meal and fish meal. Industry sources estimate 400,000 tons of urea will be fed cattle in the United States this year.

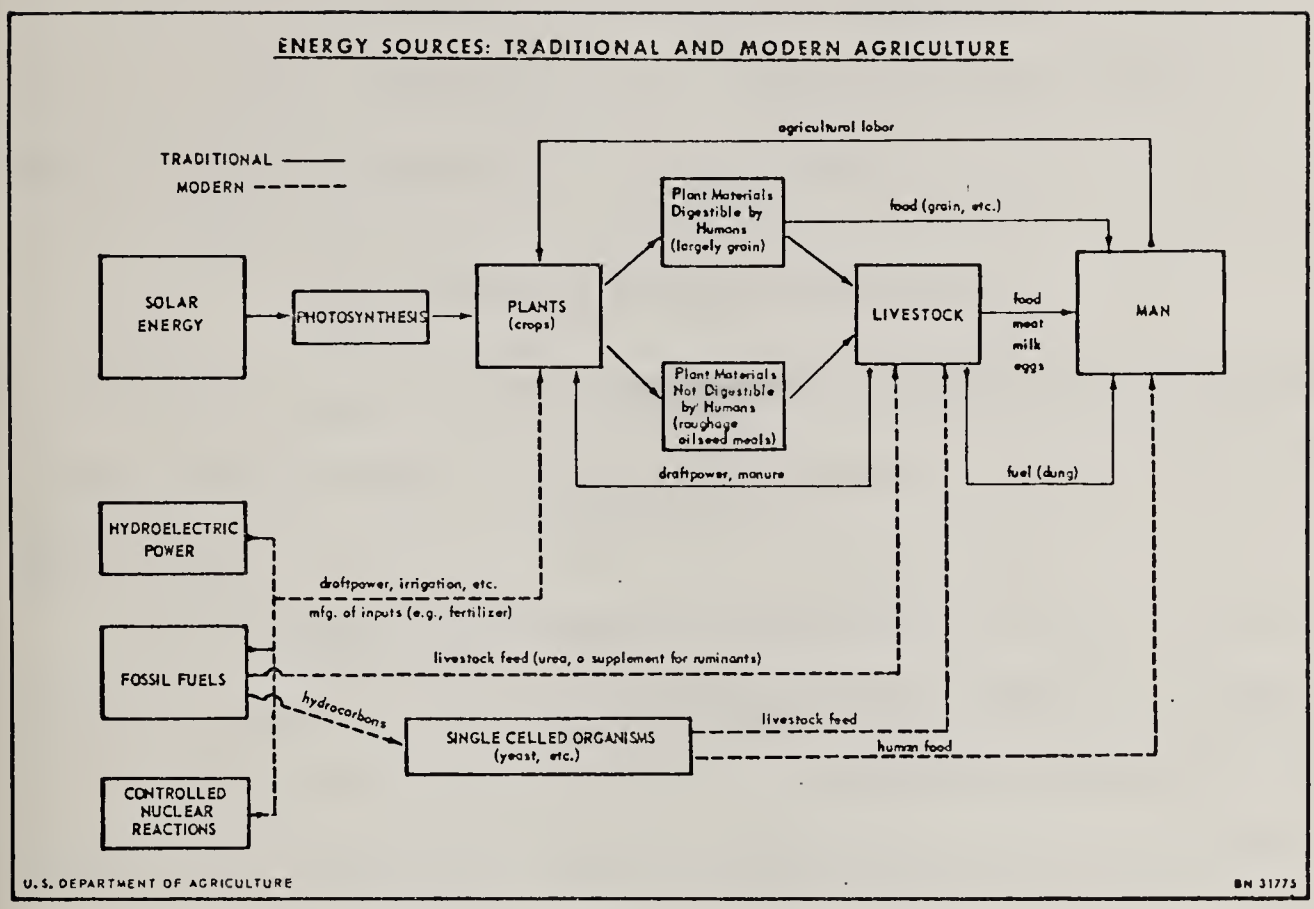
ENERGY SOURCES: TRADITIONAL AND MODERN AGRICULTURE
TRADITIONAL
MODERN
agricultural labor
SOLAR ENERGY
PHOTOSYNTHESIS
PLANTS (crops)
Plant Materials Digestible by Humans (largely grain)
Plant Materials Not Digestible by Humans (roughage oilseed meals)
food (grain, etc.)
LIVESTOCK
food
meat
milk
eggs
MAN
draftpower, manure
fuel (dung)
HYDROELECTRIC POWER
draftpower, irrigation, etc.
mfg. of inputs (e.g., fertilizer)
FOSSIL FUELS
livestock feed (urea, o supplement for ruminants)
hydrocarbons
SINGLE CELLED ORGANISMS (yeast, etc.)
livestock feed
human food
CONTROLLED NUCLEAR REACTIONS
U. S. DEPARTMENT OF AGRICULTURE
BN 31775

Figure 2

Perhaps the potentially most promising use of urea as a livestock feeding supplement is in the tropics, where large quantities of low protein roughage can be efficiently produced with the abundance of sunlight. Relatively little attention has been given to investigating and exploiting this possibility.

Augmenting The Crops-Livestock Cycle

The third subsystem we will analyze is actually an amplification of part of the second. It deals with alternative means of meeting man's protein needs.

The conventional way to improve the quality of diets is to feed increasing quantities of grain to animals, which convert it to high-protein meat, milk and eggs. This is very costly in terms of resource requirements. Raising the level of nutrition in the less developed countries to that of North America would require an increase in annual grain supplies from the current average of about 400 pounds per capita to 1,600 pounds. (See Figure 3.)

Given the costliness of this method for the world's low income peoples, widespread efforts are underway to discover shortcuts which will enable the less developed countries to attain the quality diets while still at a relatively low income level. Several promising approaches are at hand. (See Figure 4.)

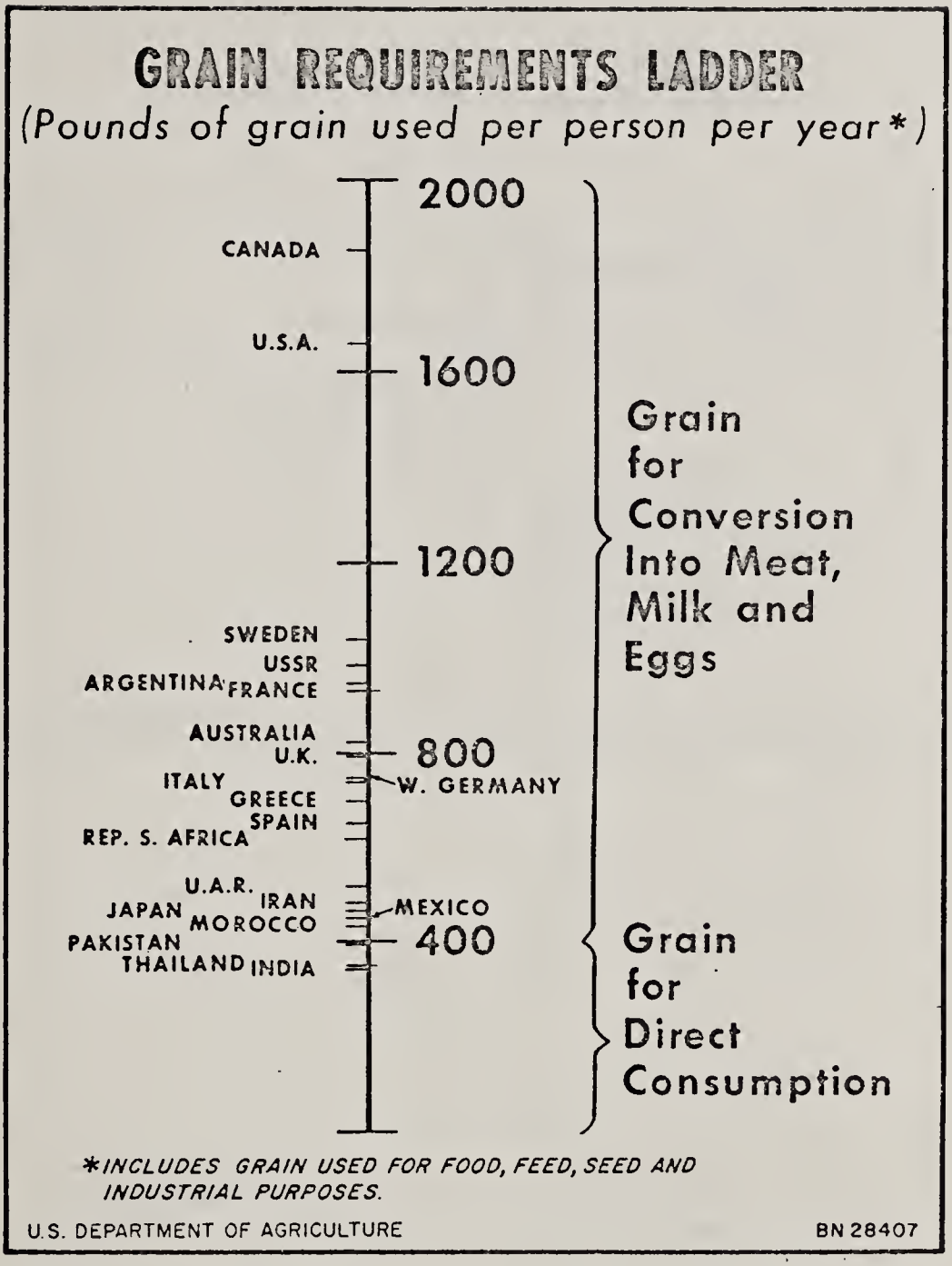
GRAIN REQUIREMENTS LADDER
(Pounds of grain used per person per year*)
2000
CANADA
U.S.A.
1600
1200
SWEDEN
USSR
ARGENTINA
FRANCE
AUSTRALIA
U.K.
800
ITALY
W. GERMANY
GREECE
SPAIN
REP. S. AFRICA
U.A.R.
IRAN
MEXICO
JAPAN
MOROCCO
PAKISTAN
400
THAILAND
INDIA
Grain for Conversion Into Meat, Milk and Eggs
Grain for Direct Consumption
*INCLUDES GRAIN USED FOR FOOD, FEED, SEED AND INDUSTRIAL PURPOSES.
U.S. DEPARTMENT OF AGRICULTURE
BN 28407

Figure 3

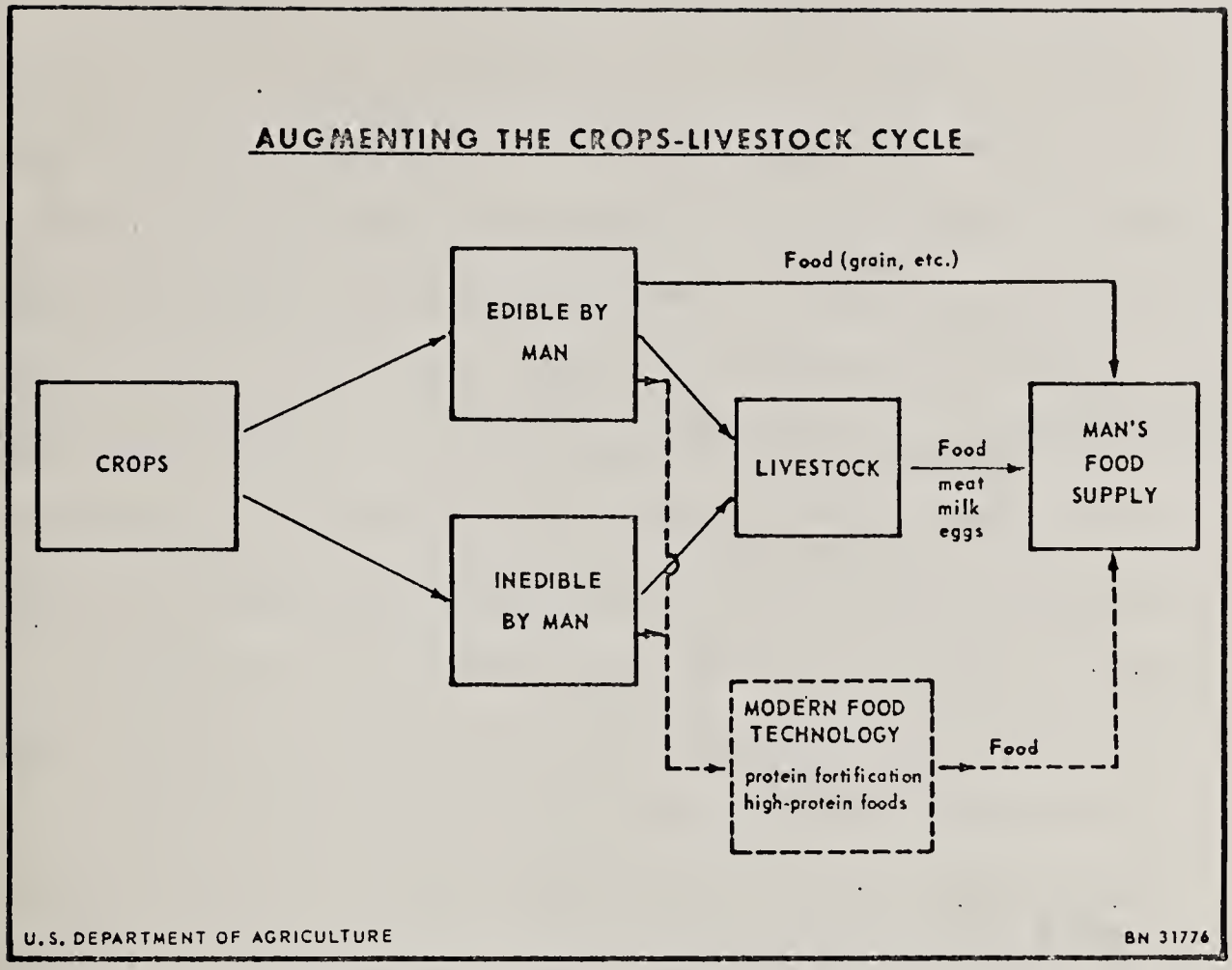
AUGMENTING THE CROPS-LIVESTOCK CYCLE
Food (grain, etc.)
EDIBLE BY MAN
CROPS
LIVESTOCK
Food
meat
milk
eggs
MAN'S FOOD SUPPLY
INEDIBLE BY MAN
MODERN FOOD TECHNOLOGY
protein fortification
high-protein foods
Food
U.S. DEPARTMENT OF AGRICULTURE
BN 31776

Figure 4

Fortification of Cereal Protein

The quality of cereal proteins can be greatly improved by adding deficient amino acids. The addition of a few pounds of lysine per ton of wheat, costing about $2 per ton of wheat fortified, raises the quality of wheat protein to roughly that of milk protein. Bread from government bakeries in Bombay and Madras is now being fortified with lysine as well as the more traditional vitamins and minerals. This bread, now selling on the black market, may be the most nutritionally potent bread marketed anywhere in the world. Importantly, it is inducing private sector competitors to fortify their products as well.

The addition of tryptophan and methionine to corn, and lysine and threonine to rice, can also dramatically improve protein quality. The exciting thing about fortifying cereals with synthetic amino acids is that it does not require any changes in taste or consumption patterns. It provides high quality protein at only a fraction of the cost of most livestock product proteins.

New Protein Foods

The prospect of developing less costly high protein foods as alternatives to livestock products is attracting the attention of the U. S. food industry. Industry has apparently decided it can produce reasonable facsimiles of almost any food products the livestock industry can produce but at a lower cost, using vegetable materials. Included in this category would be such products as oleomargarine substituting for butter, hydrogenated vegetable shortenings for lard, and imitation meats and milks derived entirely from vegetable sources.

Another line of research and development is directed toward the design of nutritionally superior foods which are not imitations of livestock products but which are appealing in their own right and which, because they are highly nutritional, may substitute for livestock products. An example of this would be a high protein beverage, Saci, now being test marketed by Coca-Cola in Brazil, which is derived largely from soybeans, cocoa beans and sugar, products indigenous to Brazil. Roughly the equivalant of milk nutritionally, this beverage is a Brazilian version of chocolate milk without the cow.

Protein deficient diets in the less developed countries are due more to the failure to fully utilize available protein than to an actual shortage. Oilseed meals remaining after the extraction of vegetable oil from oilseeds such as peanuts, soybeans and cottonseed are often inefficiently used at best and sometimes entirely wasted. The application of sophisticated modern food technology should make it possible to divert protein from these oilmeals, now used in large measure for livestock feed or as organic fertilizer, into human consumption channels. Estimates indicate oilseeds alone could furnish 25 million tons of protein, as much as man presently secures from animals.7/

During the past year, AID has provided financing for six U. S. food firms to investigate, design and market test new protein foods and beverages in several countries, all with dietary deficits in protein. Raw materials being used in these new protein foods include cottonseed oilmeal, soybean oilmeal, wheat and corn.

7/ Aaron M. Altschul, "Using Unused Protein Supplies, " International Agricultural Development, U. S. Department of Agriculture, February 1968, p. 15.

More Protein through Plant Breeding

Still another possibility for augmenting livestock as a source of high quality protein has been developed by plant breeders, who are now attempting to develop commercial varieties with a better balance of amino acids. A breakthrough in isolating a high-lysine gene in corn made at Purdue is leading the way in this field. Should new high protein varieties become commercially feasible, this could reduce the need for livestock proteins and could also reduce the production costs of livestock since it would reduce the requirement for protein concentrates in feed.

Importance of Time Horizon

Given the resources available to solve the food problem in the less developed countries, are we using them in an optimal fashion? This is the question continually confronting the systems analyst. Optimal solutions can be defined only in terms of some fixed time horizon. If our planning horizon is limited to one year, the mix of efforts designed to reach our goals will be very different than if it extends 20 years into the future.

If our concern is with the current year only, we would be well advised to use most of our resources to provide food aid. AID financed fertilizer shipments will not show up in the form of additional food production until next year. Investments in family planning are a waste in terms of the current year; they will not measurably reduce the demand for food for several years to come.

Determining an optimal combination of resource mix is not possible with an indeterminate time horizon. Planning horizons of many resource-allocating bodies, particularly governments, are quite short. At the outside, they may extend four, five or seven years into the future depending on the duration of multi-year development plans or Planning, Programming and Budgeting time frames. The food problem by its nature requires an extended time frame, reaching perhaps a quarter century into the future.

Conclusions

Both the lack of data on so many aspects of agriculture in the less developed countries, and the inability to significantly influence some of the economic, social and political variables, prevents the use of the elaborately detailed systems used so successfully in, say, our space program. But, there is, nontheless, an opportunity for using the principles of systems analysis to increase the efficiency with which available resources are used.

Evidence now becoming available suggests that several less developed countries may be achieving an agricultural takeoff. U. S. assistance from both public, in the form of food aid and technical assistance, and private, in the form of fertilizer plants and new high yielding varieties of wheat and rice, have played an important role.

Foodgrain production in India this year, boosted by good weather, is 32 percent above last year's drought depressed level and 12 percent above the previous record.

Pakistan's wheat harvest is expected to be 20 percent above the previous record. Iran is self-sufficient this year in wheat; Kenya has an exportable surplus of its food staple, corn; and the Philippines is virtually self-sufficient in rice this year for the first time in recent memory.

Following are examples of some of the more significant advances in U. S. assistance, many of which have figured heavily in this turnaround.

(1) The expansion of AID-funded agricultural activities, from less than $200 million in the early 1960's to nearly $600 million this year, has contributed heavily to the increased availability of farm inputs such as fertilizer and pesticides and to expanded irrigation works, farm-to-market roads and other activities needed to strengthen the agricultural infrastructure. This has encouraged agribusiness investments both from indigenous and external sources, notably the United States.

(2) Discarding the surplus concept in the U. S. food aid program, coupled with adjustment of the domestic agricultural production pattern to meet both commercial market and concessional program needs, has made our expenditures under this program much more effective.

(3) Using food aid not only to alleviate hunger in the short-run, but also as leverage for agricultural reform and expanded resource commitments to agricultural development where needed, has multiplied the contribution of this program to solving the long term food problem several-fold.

(4) The growth in U. S. agribusiness investment in the less developed countries, particularly in fertilizer plants, has likely resulted in an increase in the yearly grain-producing capability of these countries of at least 30 million tons of grain.

(5) The high yielding varieties of wheat and rice developed by the Rockefeller and Ford Foundations for use throughout the less developed, food deficit countries may revolutionize agricultural production in these countries. Although this plant breeding activity represents an exceedingly modest investment ($15 million for rice) relative to the total U. S. agricultural assistance effort, its cost-benefit ratio is already incalculably high.

(6) The recent decision by AID to commit substantial resources (35 million dollars this fiscal year) to family planning is a major forward step, essential to the long term solution of the food problem in the less developed countries. It will complement heavy investments in several countries by the Population Council.

Questions Outstanding

While substantial progress has been made toward obtaining a more optimal allocation of resources among various forms of assistance, much more remains to be done.

Resources used for family planning have been increased, but we have not yet systematically addressed ourselves to the question, "What is the optimal allocation of resources between agriculture and family planning?"

Available evidence indicates family planning should be getting a larger share but no one seems to know how much more or how rapidly it should increase. This question deserves much more attention from the systems analyst.

Within agriculture, the distribution of effort and inputs between production and marketing needs examination. At some point, as production increases, emphasis must shift from the production of food to its preservation and distribution. Evidence from some countries indicates this point may have already been passed.

The close relationship between energy consumption in the farm sector and yields per acre deserves to be translated into policies regarding energy use between industry and agriculture, between production and consumption use (e.g. lights for village homes or power for irrigation pumps) and between alternative forms of energy. The "alternative-forms-of-energy" question is both technically and economically complex but it must be analyzed if the less developed countries are to use their resources in an optimal fashion.

Exciting advances in food technology are making it possible to utilize indigenous supplies of high quality protein (e.g. cottonseed oil meal) in nutritious, appealing human foods. What should be the role of the U. S. Government in speeding the dissemination and adoption of this new technology?

Many other questions could be discussed but those discussed above provide an idea of areas where further systematic analysis is needed. In many cases, the ingredients are known, but the optimum balance isn't.

In others, the components themselves may not be fully recognized.

From this discussion it is clear there is a need for sophistication in solving the world food problem. Systems analysis can help provide this sophistication.