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EXPLORING NATIONAL FOOD POLICIES IN AN INTERNATIONAL SETTING: THE FOOD AND AGRICULTURE PROGRAM OF IIASA

Kirit S. Parikh

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANLALYSIS
A-2361 Laxenburg, Austria

1. GENESIS

The food problems – efficient production or procurement of food and its appropriate distribution among members of family and society – are endemic problems of mankind. Yet the nature and dimension of these problems have been changing over time. As economic systems have developed, specialization has increased; and this has lead to increased interdependence of rural and urban areas, of agricultural and nonagricultural sectors and of nations. The importance of public policies in resolving these problems has grown with the growth of interdependence. The growing interdependence of nations, reflected in increasing volumes of food trade, requires that the exploration of national policy alternatives be carried out in the context of international trade, aid, and capital flows.

The International Institute for Applied Systems Analysis (IIASA), a nongovernmental multidisciplinary international research institution, provides an excellent setting in which to undertake a research effort to explore national and international food policy options. The Food and Agriculture Program (FAP) of IIASA, initiated in 1976, was conceived with recognition of the importance of interdependence and an appreciation of the unique advantages offered by IIASA. The experience so far has borne out these feelings.

Preliminary work on IIASA's Food and Agriculture Program was begun in 1976 under the leadership of Ferenc Rabar of Hungary. It was formally recognized as a "program" by the Council of IIASA in 1977 for a five year duration, from 1977 through 1981. In IIASA's research organization, a major research activity which cuts across the various areas organized along disciplinary lines is considered as a program. The FAP was the second program of the institute, the first one being the Energy Program.

The FAP was started with broad objectives as follows:

To Evaluate the Nature and Dimensions of the World Food Situation

To Identify Factors Affecting It

To Suggest Policy Alternatives at National, Regional and Global Levels

- **To Alleviate Current Food Problems and**
- **To Prevent Future Ones**

Although the program began with a concern with policies over a 5-15 year time horizon, it was recognized that a long-term perspective is also required for a comprehensive understanding of the food problems of the world. Thus the original objectives were supplemented with the following qualification:

Solutions to current problems should be consistent with paths that lead to a

- **Sustainable**
- **Equitable and**
- **Resilient World**

That Can Meet the Food Needs of the Global Population, Which May Double by 2030.

To realize these objectives the FAP is organized around two major tasks: Task 1, called "Strategies: National Policy Models for Food and Agriculture," in which the present shortrun problems of policy are explored; and Task 2, entitled: "Technological Transformations in Agriculture: Resource Limitations and Environmental Consequences," in which the questions raised by a long-term perspective are investigated. I have described the background, issues, approach, the point of departure and the status of these two tasks in turn, and have also indicated the connection between the tasks.

In the following section a description of the short-term problems as we perceive them is given. The specific policy issues addressed are described in Section 3, along with an outline of the approach considered appropriate for addressing the issues. Section 4 indicates the point of departure of the FAP compared to other past efforts. The network approach of collaborating institutions followed for implementation of the program is described in Section 5. Sections 6 to 9 cover the same topics as Sections 3 to 6 for the long-term food problems. Finally, Section 10 indicates the way in which our investigations of short and longrun problems complement each other.

* * *

2. Task 1: STRATEGIES: National Policy Models for Food and Agriculture

THE FOOD PROBLEM –PRESENT AND PRESSING

What is the food problem of the world? What are the problems of nations, developing and developed, exporting and importing? What are the major concerns from short- and long-term perspectives?

We began with a set of perceptions:

(a) *Large numbers of people go hungry in the world today, although globally adequate food is available. This is true even in nations with adequate food on the average, because of improper distribution of income and food.*

The per capita consumption of calories over the past few years is shown in Table 1. Even when one recognizes the considerable uncertainties of prescribing norms for calorie requirements, a number of observations can be made from the table. Globally adequate food is available, and all developed regions have adequate food supply. The developing countries as a group have inadequate or barely adequate (if one considers the uncertainty of the norms) food supply. Though the situation is improving, it is improving slowly.

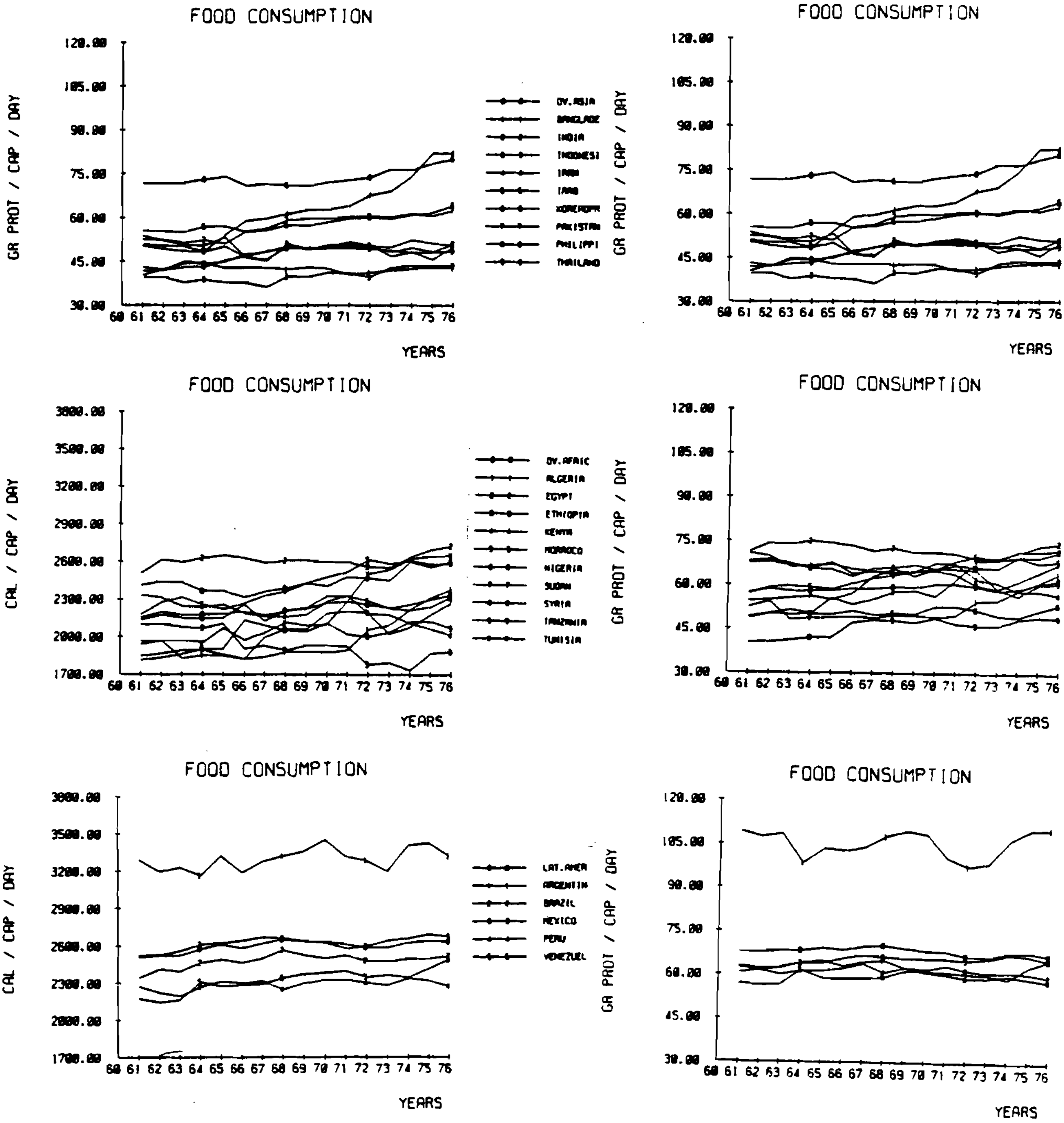
Table 1. PER CAPUT DAILY SUPPLY OF CALORIES

Region	Calorie supply				Supply as percent of requirement			
	1961-63	1964-66	1969-71	1972-74	1961-63	1964-66	1969-71	1972-74
	... Kilocalories per caput				.... Percent			
Developed market economies	3 130	3 170	3 280	3 340	123	124	129	131
North America	3 320	3 360	3 500	3 530	126	127	133	134
Western Europe	3 200	3 230	3 330	3 390	125	126	130	132
Oceania	3 300	3 320	3 320	3 370	124	125	125	127
Other developed market economies	2 570	2 650	2 760	2 850	109	112	117	121
Eastern Europe and the USSR	3 240	3 270	3 420	3 460	126	127	133	135
All developed countries	3 170	3 200	3 330	3 380	124	125	132	132
Developing market economies	2 110	2 130	2 190	2 180	92	93	96	95
Africa	2 070	2 100	2 150	2 110	89	90	92	91
Latin America	2 400	2 470	2 530	2 540	101	104	106	107
Near East	2 290	2 340	2 410	2 440	93	95	98	100
Far East	2 010	2 000	2 070	2 040	91	90	94	92
Other developing market economies	2 130	2 200	2 290	2 340	93	96	100	103
Asian centrally planned economies	1 960	2 110	2 220	2 290	83	90	94	97
All developing countries	2 060	2 120	2 200	2 210	89	92	95	96
World	2 410	2 460	2 540	2 550	101	103	106	107

Source: *The Fourth World Food Survey, 1977.* Table 1.3.1, page 16. FAO, 1977.

Of course, even among the developing countries the situation varies from country to country, and some countries are much more seriously affected by inadequate food supply. Unfortunately for many of these countries, the situation does not seem to be improving. This can be seen in Figure 1, in which the per capita calorie and protein consumption for several countries from 1960 to 1976 are plotted.

Figure 1. PER CAPITA CONSUMPTION OF CALORIES AND PROTEINS



How important it is to consider distribution in appraising the adequacy of food consumption within a country can be seen in Table 2, where distribution of daily calorie consumption for India is shown. It is seen that in 1973-74, 38% of the population had a daily deficit in calorie consumption, although for the country as a whole there was no calorie deficit.* Moreover, the problem for the poorest classes is severe, as 5 percent of the population had a deficit of 1000 calories/person/day, and another 5 percent had a deficit of 680 calories/person/day.

Table 2. INDIA, 1974 – DISTRIBUTION OF CALORIE CONSUMPTION

Income Class	Population Percent of Total	Daily Calorie Consumption Per Person	Daily Calorie Deficit Per Person
1	5	1102	1108
2	5	1528	682
3	10	1647	563
4	18	1904	206
5	20	2115	-
6	21	2495	-
7	11	2805	-
8	7	3140	-
9	3	3440	-
Total	100	2217	-

Based on National Sample Survey, 28th Round, October, 1973-June, 1974.

* The calorie consumption figures of Table 2 indicate that there was no deficit in India for 1973-74, whereas FAO data on which Table 1 is based show that the average calorie supply for India for 1972-74 was 1910 calories. This discrepancy may be accounted for by yearly variations and differences in methods of estimation. In any case the the point made is valid, even more so if one were to rely on FAO data.

A similar picture emerges from data for Kenya given in Table 3. For the country as a whole there is only a marginal calorie deficit, yet 40 percent of the rural population has a daily calorie deficit of 640 calories, and in urban areas 40 percent has a deficit of 340 calories.

Table 3. KENYA, 1975 – DISTRIBUTION OF CALORIE CONSUMPTION

Rural Income Class	% Rural Pop.	Per Capita Daily Calorie Consumption	Per Capita Daily Deficit*
1	39	1578	642
2	32	2077	143
3	19	2545	-
4	5	2867	-
5	2	2788	-
6	4	3036	-
Total	100	2069	151

* Moderately active requirement 2200 calories per day.

Urban Income Class	% Urban Pop.	Per Capita Daily Calorie Consumption	Per Capita Daily Deficit ** Per Person
1	42	1787	343
2	25	2117	13
3	33	2453	-
Total	100	2086	44

** Urban light activity requirement 2130 calories.

Source: *M. M. Shah, Calorie Demand Projections Incorporating Urbanization and Income Distribution.* FAP, IIASA, 1978.

That the extent of the problem is significant is obvious from the estimate of the number of people in absolute poverty. Although the estimates vary from source to source, all of them indicate a sizeable problem. In 1980 in developing countries, excluding China and other centrally planned economies, the World Develoment Report (World Bank, 1980, p. 33) estimated that approximately 780 million people did not have enough income to buy adequate food and minimal clothing. The FAO estimates show that in 1972-74, 455 million people in these countries had food intake below the critical limit of 1-2 basic metabolic rate (BMR).

The problem is persistent, as can be seen from the estimates of the percentage of the rural population in absolute poverty in India, which has a large portion of the world's poor. The data in Table 4 show that there has been no significant trend in the percentage of the rural population in poverty over the period 1957-1974.

Table 4. PERCENTAGE OF RURAL POPULATION IN POVERTY IN INDIA (BY STATES)

	1957-58	59-60	60-61	61-62	63-64	64-65	65-66	66-67	67-68	68-69	70-71	73-74
Andhra Pradesh	54	49	50	47	46	42	45	48	46	47	41	40
Assam	28	31	26	30	24	24	31	47	38	47	35	39
Bihar	60	56	42	50	52	54	60	74	71	59	59	58
Gujarat	•	42	32	40	46	50	51	54	51	43	44	36
Karnataka	41	49	39	35	51	55	64	60	57	59	47	47
Kerala	60	62	58	50	53	61	71	67	63	65	62	49
Madhya Pradesh	58	46	44	40	44	42	47	58	62	56	53	52
Maharashira	•	55	48	44	48	59	58	63	57	55	47	50
Orissa	67	63	62	49	60	62	62	64	65	71	65	58
Punjab & Haryana	28	24	19	22	29	27	27	30	34	24	24	23
Rajasthan	33	n.a.	32	33	33	32	31	37	36	41	42	30
Tamil Nadu	66	64	54	51	52	57	60	63	58	61	5748	
Uttar Pradesh	52	37	38	35	57	54	47	55	60	46	41	47
West Bengal	62	61	40	58	63	64	57	64	80	75	70	66
INDIA (Weighted Averages)	53	49	42	42	49	50	51	57	58	53	49	48

Source: Ahluwalia M.S. (1978). Rural Poverty and Agricultural Performance in India, *Journal of Development Studies*, Vol. v14, April, 1978, pp.298-323.

(b) *National policies are the important policies in dealing with the problem of hunger, either through increased production and/or through more equitable distribution.*

Increasing food production in food deficient countries may seem to be the obvious answer to meeting the problem of hunger. Yet production increases indicated by trend rates in the developing countries would be inadequate and in fact would lead to reduced self-sufficiency in food production. This can be seen from the FAO's projections given in Table 5. Though average consumption increases, the reduction in the number of undernourished people is marginal. The cereal imports of deficit countries increase dramatically. To offset the agricultural commodity trade balance, these countries would have to increase their exports of nonagricultural products substantially. In order to accomplish this, national governments would have to step up their efforts to create faster economic growth. This in turn can lead to increased import needs for capital goods and can further aggravate the Balance of Payments situation. Moreover, expansion of such exports may not be easy to realize without a change in the international economic order.

Table 5.

FAO'S AT 2000 PROJECTIONS

For 90 Developing Countries based on Trend Rates

	1980	2000
• Aggregate Calorie Self Sufficiency Ratio	.92	.80
• Cereal Imports of Deficit Countries	47	180 million tons
• Net Meat Deficit	0.4* Surplus	14 million tons
• Agri. Commodity Trade Balance (1975 billion $)	6 Surplus	36 billion $ deficit
• Average Calorie Consumption per Person per Day	2278	2489 Calorie
• Population Undernourished	415* (22%)	390 million (11%)

*1974–75

Source: *Agriculture: Toward 2000.* FAO, c79/24, July, 1979.

To step up agricultural growth rates in developing countries beyond the trend rates, increased availability of inputs and capital resources is required. Table 6 summarizes these needs for selected inputs for FAO's normative scenario projections. Realization of such growth rates would call not only for increased availability of inputs and capital resources but also for appropriate national policies which persuade the producers to produce more. Redistributive policies to bring about more equitable distibution of food are also largely matters of national policies.

FAO projection methodology is based mainly on technological considerations of input requirements for obtaining different outputs. The questions of appropriate government policies as well as of consistency of production, income, and demand are not explored by the FAO study.

Table 6.

PRODUCTION AND KEY INPUTS – 90 DEVELOPING COUNTRIES
(U.S. $ 1975: Index (1975* = 100) unless otherwise stated)

			Annual Growth rates	
	1980	2000	1963* 1975*	1980 2000
Gross value of agricultural production	115	244	2.6	3.8
Gross value of crop production	114	232	2.6	3.6
Arable area (million ha.)	744	936	0.8	1.2
Irrigated area (million ha.)	104	152	2.0	1.9
Yield	112	181	1.8	2.4
Fertilizer (million tons – nutrients)	19	94	11.8	8.2
Tractors (thousands)	2327	9860	7.7	7.5
Gross value of livestock production	115	288	2.9	4.7
Cereal feed (million tons)	57	190	5.4	6.2

Source: "Agriculture: Toward 2000," FAO, c79/24, July, 1979.

Increased production is not in itself adequate to ensure that all will have enough to eat. Appropriate government policies are necessary, too. This is seen from the analysis of the circumstances associated with four famines shown in Table 7. In three of the four famines the per capita food availability had not declined, and during the Bengal famine, which had the highest number of deaths (1.5 to 3 million out of 6 million) among the four famines, the economy of Bengal was booming.

Table 7. COMPARATIVE ANALYSIS OF FOUR FAMINES

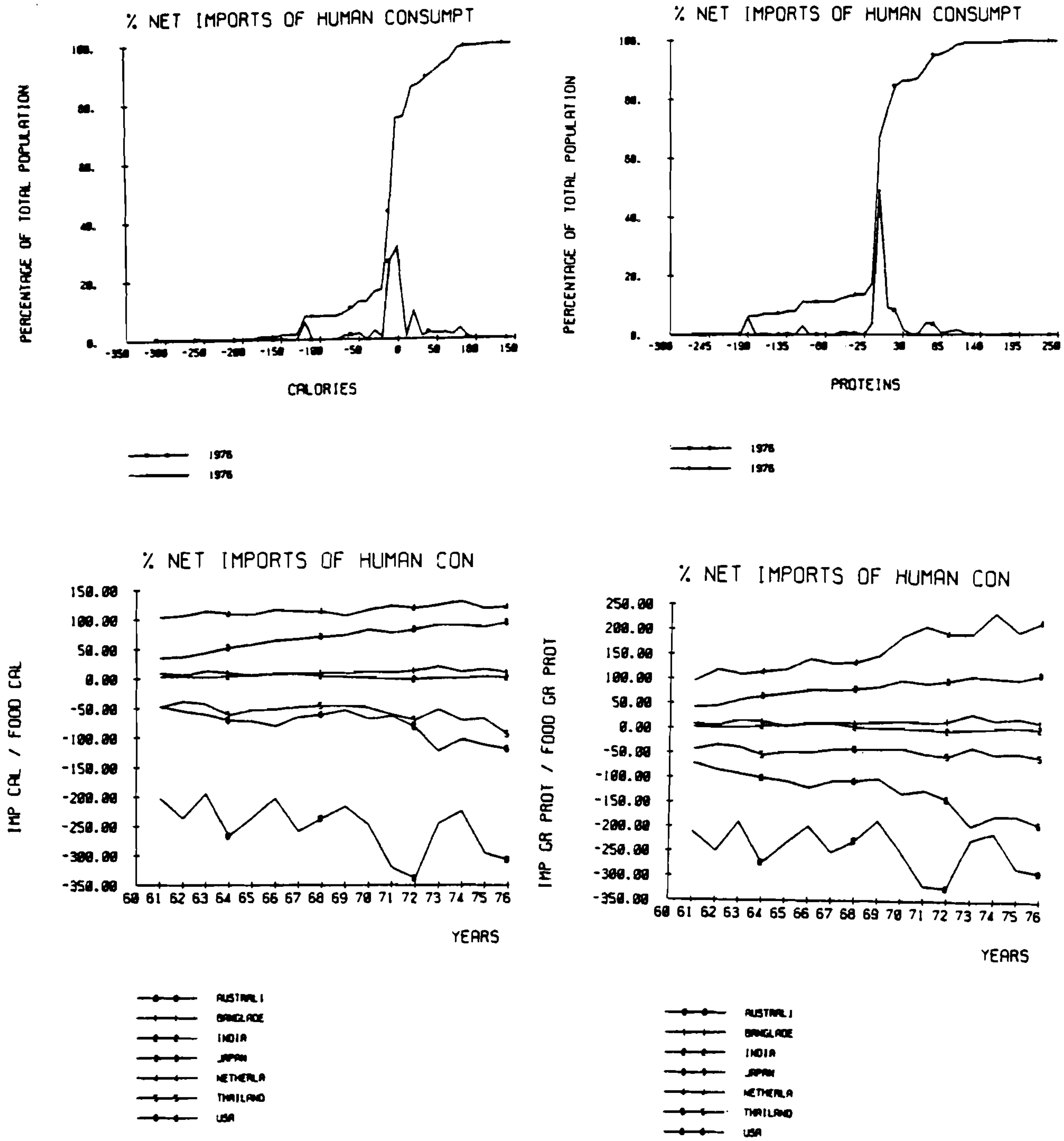
Which famine?	Was there a food availability collapse?	Which occupation group provided the largest number of famine victims?	Did that group suffer substantial endowment loss?	Did that group suffer exchange entitlement shifts?	Did that group suffer direct entitlement failure?	Did that group suffer trade entitlement failure?	What was the general economic climate?
Bengal famine 1943	No	Rural labour	No	Yes	No	Yes	Boom
Ethiopian famine (Wollo) 1973	No	Farmer	A little, yes	Yes	Yes	No	Slump
Ethiopian famine (Harerghe) 1974	Yes	Pastoralist	Yes	Yes	Yes	Yes	Slump
Bangladesh famine 1974	No	Rural labour	Earlier, yes	Yes	No	Yes	Mixed

Source: Sen Amartya, *Ingredients of Famine Analysis, Availability and Entitlement.* Working Paper No. 210, Department of Economics, Cornell University, October, 1979.

(c) *Though national governments are the highest decision making bodies in the world, the interdependence of nations is critical in determining many national policy options. Trade in food and agricultural products forms a sizeable part of the total trade of many countries, and these countries are affected by the policies of other countries.*

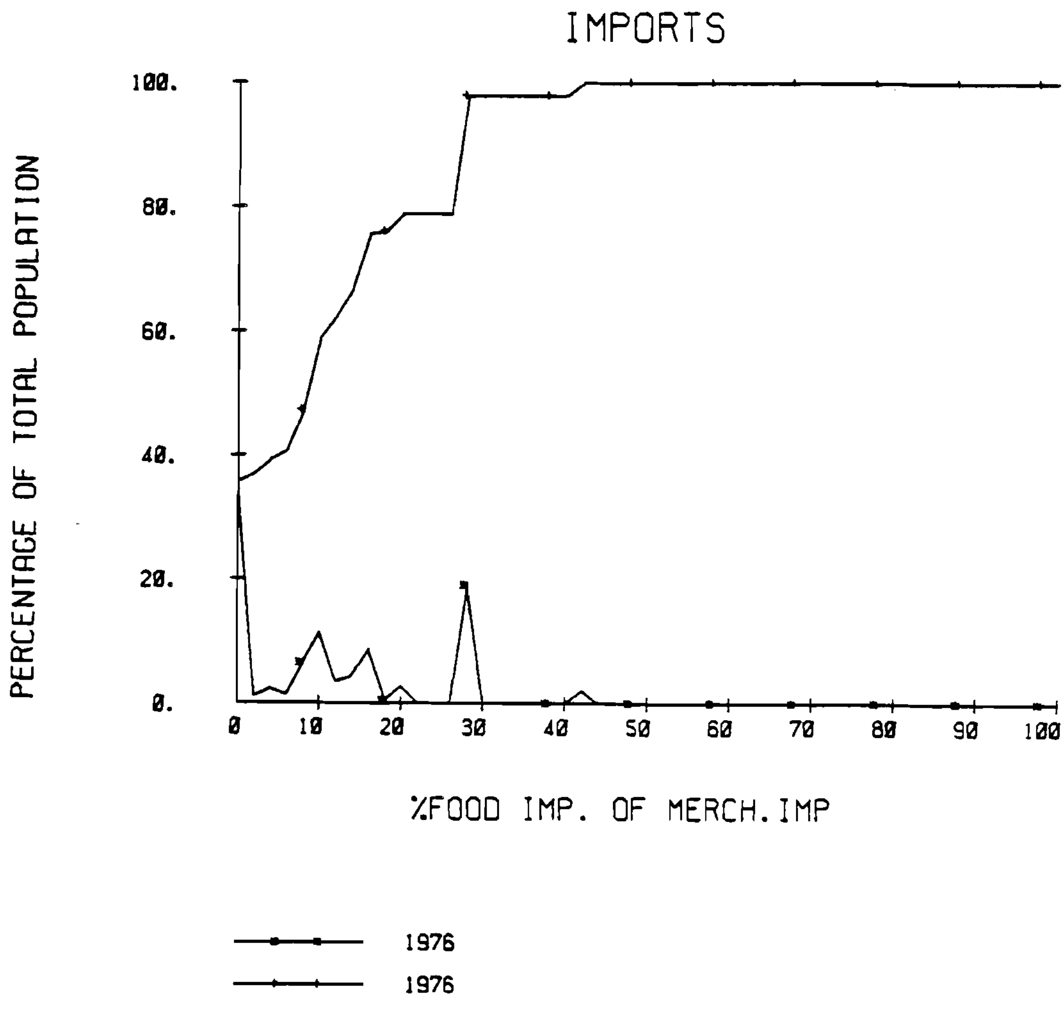
The importance of traded calories in human consumption is shown in Figure 2. The population of the countries from 56 selected countries are grouped together based on the net import of calories and proteins as percentages of human consumption of calories and protein and are plotted as a percentage of the total population of the selected 56 countries. It is seen that 15 percent of the population depends on net imports of calories for more than 30 percent of its consumption. Figure 2 also shows net imports of calories and proteins as percentages of human consumption in selected countries. Since the Netherlands imports feedgrains and protein feeds for livestock, its net imports exceed 100 percent of its final human consumption as computed in terms of both calories and proteins.

Figure 2. IMPORTANCE OF TRADED CALORIES IN HUMAN CONSUMPTION



Moreover, agricultural imports form a sizeable part of the trade of many countries. This can be seen from Figure 3, which gives the distribution of population by share of agricultural imports in the total merchandise imports of the country. In value terms 40 percent of the population of the world live in countries for which this share was more than 10%, whereas for 20 percent of the population they exceeded 20 percent.

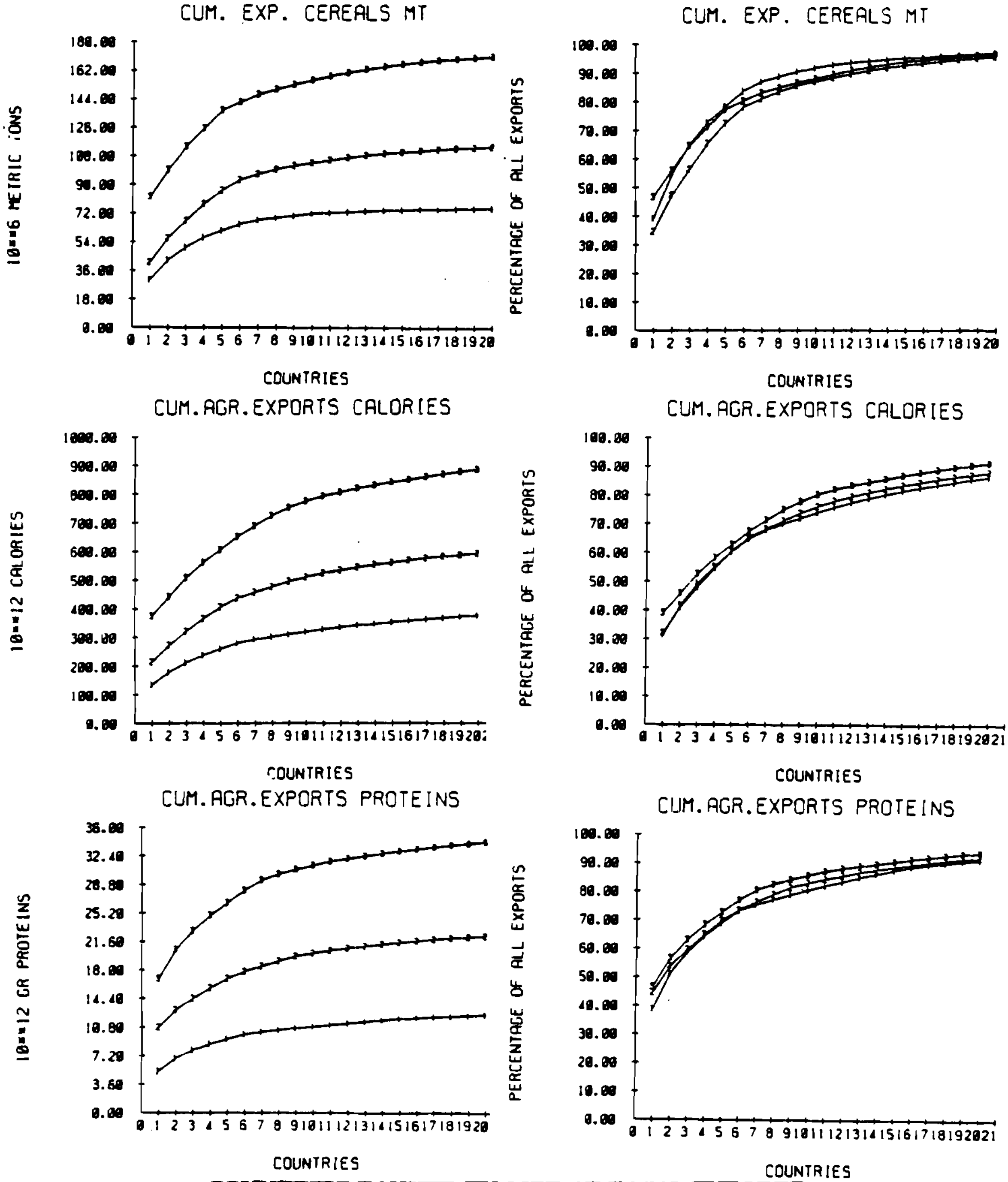
Figure 3. IMPORTANCE OF AGRICULTURAL IMPORTS IN TRADE



VALUE OF FOOD IMPORTS AS PERCENT OF MERCHANDISE IMPORTS

Policies of countries are affected by the policies of other countries to a greater extent than may appear from the shares of agricultural trade in total trade. This is because agricultural trade is dominated by a few countries, as can be seen from Figures 4a, 4b and 4c. Five exporting countries account for more than 60 percent of the total exports of calories and 70 percent of exports of cereals and proteins.

Figures 4a, 4b and 4c.

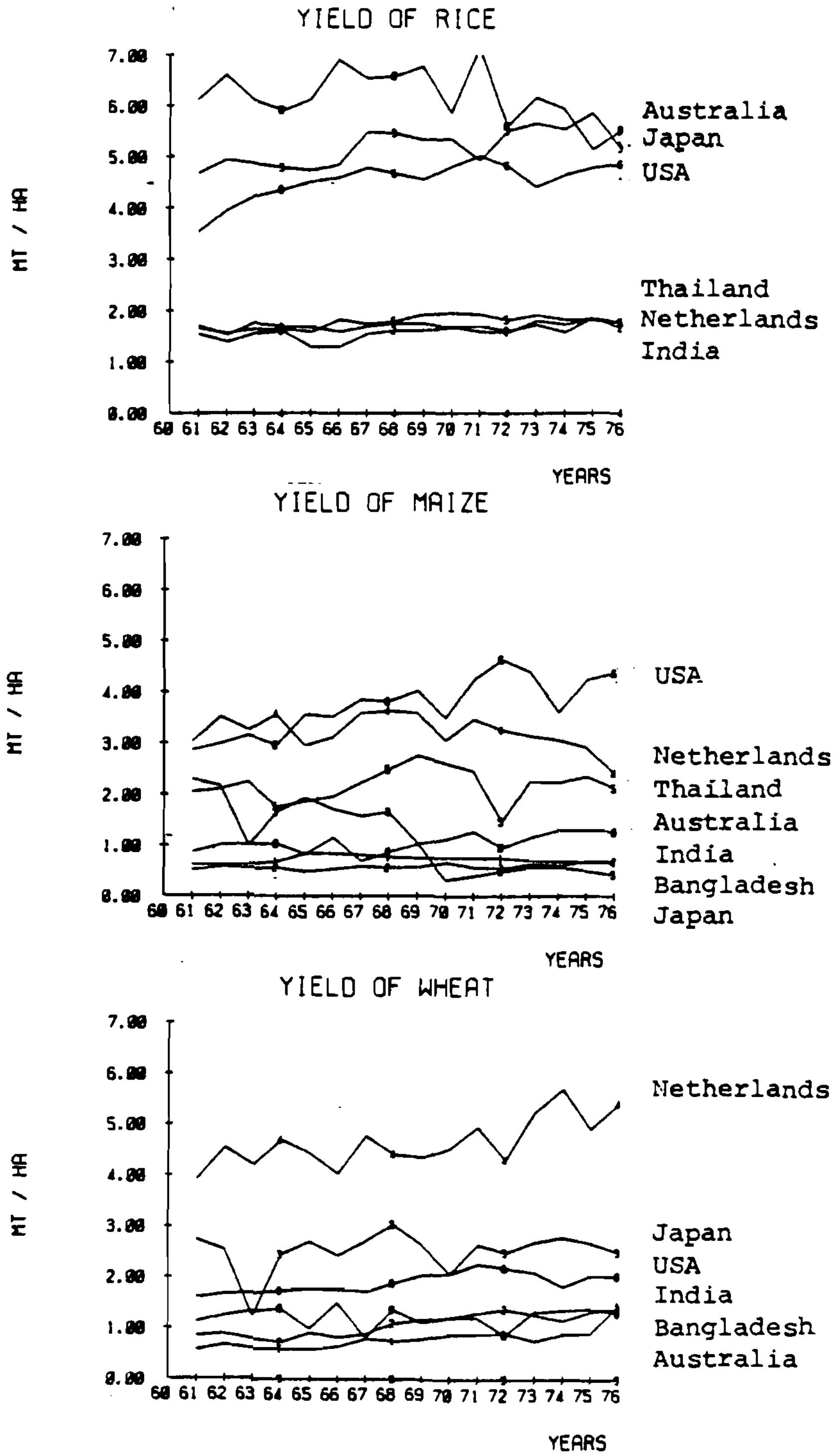


COUNTRIES RANKED BY SIZE OF TOTAL EXPORTS

(d) *The inherent uncertainty in agricultural production implies that even normally self- sufficient countries may need to depend on trade in exceptional years.*

Yields of rice, wheat, and maize given in Figures 5a, 5b and 5c for selected countries show that fluctuations in yield are important for both high yield and low yield countries, and that countries have found it neither easy nor economically feasible to eliminate flucutations in agricultural production.

Figures 5a, 5b and 5c.



(e) *The agricultural sector is embedded in the national economy and should be treated in that setting. In most countries food and agricultural policies dominate economic policies, since food prices affect everyone in the economy.*

In summary, we concluded that the present food problem is a problem of inadequate food consumption by a large number of people as a result of insufficient income and improper distribution, which is accentuated by uncertain climatic conditions, and which is amenable mainly to national policies, which are constrained by the actions of other countries. Thus the food and agriculture system of the world is best viewed as a set of *national* agriculture systems *embedded* in national economies *affected* by national governments' policies and *interacting* with each other.

3. ISSUES AND APPROACH

The major questions that emerge out of the broad background of the preceding section are, what national and international policies promote agricultural growth, encourage efficiency in production and reduce inequities of distribution?

Some of the important policy questions that need to be explored are listed below:

National Policies

For Growth:

(a) What is the impact of price policies? To what extent do price incentives lead to increased production?

(b) What is the impact of the development of irrigation on production, prices and consumption?

(c) How do fertilizer availability and prices affect agricultural production?

(d) What is a desireable pace for the introduction of advanced technology and mechanization?

(e) How does agricultural growth affect employment and migration patterns?

For Equity

(f) Does a price increase in the cities reach the farmers in the countryside? Does it reach the small farmers?

(g) When the average agricultural income goes up, do the poor farmers benefit?

(h) How can adequate food be provided to poor consumers? How effective are public food distribution programs? Is it better to ration food or to issue food stamps?

(i) What role can a food-for-works program play in relieving rural poverty?

(j) How do changes in land holding patterns and in tenancy structure affect production and consumption?

For Stability

(k) Is price stabilization desireable? Do stable prices benefit producers?

(l) What is an appropriate national buffer stock policy to stabilize prices?

(m) How can stable income for farmers be ensured? What are the costs and benefits of alternative schemes of deficiency payments and set-asides?

For Self-Reliance

(n) What is an appropriate agricultural self-sufficiency target for a country? How can that be realized?

(o) What are ways of effectively utilizing food aid? Which is more effective—food aid or general aid?

(p) What are appropriate trade policies? To what extent should the country insulate domestic markets from world markets? What are the impacts of trade quotas, of tariffs and of export incentives?

International Policies

(a) Adoption of large-scale programs of alcohol production/energy plantations by energy-deficient countries with a food surplus.

(b) Establishment of an international buffer stock agency that tries to ensure that prices for specific commodities (1) remain at a given level or (2) remain within a prescribed range.

(c) Agreement to keep world market prices at given levels by adjusting internal prices (1) for all nations or (2) for a subset of nations.

(d) Interpretation of the preceding agreement as a compensatory finance scheme in which developing nations are indemnified against adverse developments on the world market.

(e) Establishment of a buffer stock of the size required to withstand a shock such as might result from a series of crop failures.

(f) Establishment of international food transfers of the size required to banish hunger within a prescribed time limit.

Policy Evaluation

Policies have to be evaluated in the context of the objectives of national governments. Growth, equity, stability and sustainability--political and ecological--may in general be considered to be the objectives of governments' economic policies. Specific policy instruments, even policies relating to primarily agricultural issues, affect these objectives differently. Table 8 summarizes the possible impacts of some important policies on these objectives in a large developing country such as India.

Table 8.

Effects on Objectives of Various Policies

Policy Instrument	Growth	Equity	Stability	Sustain-ability
	Objectives			
Investment Level	↑	↓↑	↓	
Income Tax	?	↑?		
Indirect Tax	↑	↓	↓	
Irrigation	↑	↓	↑	↓
HYY	↑	↓	↓?	↓
Fertilizers	↑	↑↓		↓
Mechanization	↑?	↓		
Land Ceiling & Redistribution	↑↓	↑		↑↓
Tenancy Reforms	↑	↑		↑?↓
Public Food Distrib.	↓	↑	↑	↑
Procurement of Food Grains	↓	↑		
Bufferstock Operation	↓?		↑	↑
Food-Aid	↑↓?	↑	↑	↓

↑ Furthers Objective
↓ Adverse Effect on Objective
? Questionable Effect

As an example, consider the impact of food aid on the growth of the economy of a developing country. The outcome would depend on government policies, and the outcome is indeterminate, as is shown in the last line in Table 8. Some of the possible outcomes are elaborated in Table 9. The outcome in a particular instance would thus depend on the totality of government policies.

Table 9.

POSSIBLE IMPACT OF FOOD AID

- **Not Accepted**
  - Ration Food
  - Excess Demand Spills into Other Goods
  - Reduced Exports
  - Reduced Investments
  - Lower Future Output
- **Accepted**
  - Distributed to Poor Only
    - No Change in Market Price
    - No Change in Future Output
  - Distributed to All in Urban Areas
    - Lower Price
    - Lower Farm Income
    - Lower Future Output

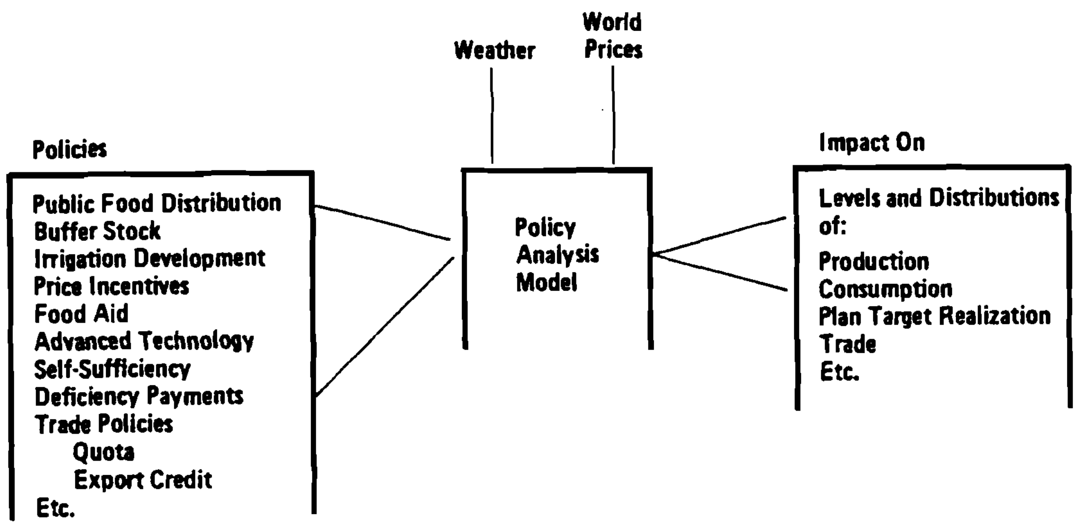
but if
  - Food Aid is Additional Aid
    - Increased Investment
    - Higher Future Output

or if
  - Food Aid Augments Government Budget
    - Lower Tax Rate
      - Reduced Investment When Aid Stopped in Future
      - Lower Future Output
    - Increased Tax Rate
      - Higher Investment
      - Higher Future Output

Thus to evaluate policies we need a policy analysis framework, or a model, which can help determine the impact of policies on various objectives as shown in Figure 6. Only then can we evaluate alternative policies. In other words, a quantitative systems analytic framework--a general equilibrium approach--is needed.

Figure 6.

- **National Policy Analysis Framework**



For realistic policy analysis, particularly for short- or medium-term policy analysis, it is better to use a descriptive as opposed to a normative framework, in which one can identify specific policy instruments with particular policy makers, and to include the reactions of various economic agents to such policies. Moreover, normative analyses often imply institutional transformations of the socio-economic framework, which is not easy to bring about in short term.

We conclude that: to attain our objectives of evaluating short- and medium-term policies to alleviate food problems we need descriptive general equilibrium models of open national economies linked together in trade, aid, and capital flows. Table 10 characterizes the FAP model system.

Table 10.

FAP MODEL SYSTEM

- **Price Endogenous**
- **Descriptive**
- **National Models**
- **Of Open Exchange Economies**
- **With Government Policies**

  for
- **Year by Year Simulations**
- **Linked Together Through**

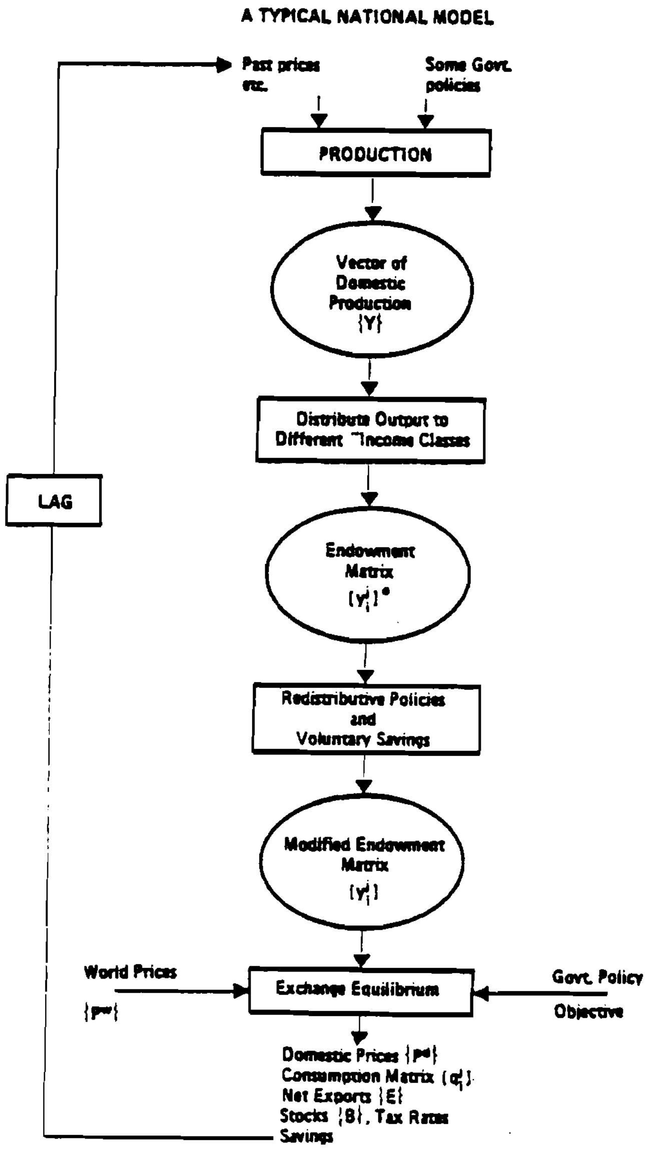
  Trade
  Aid, and
  Capital Flows

A Typical National Policy Model of FAP

The basic elements of the FAP model system are the national policy models. A particular national model has to reflect the specific problems of interest to that particular nation. Thus the national models differ from each other in their structure and in their description of government policies. The FAP model system permits the linking of such diverse models but requires that the models meet a few conditions. They have to have a common sector classification and units and some additional technical requirements which are considered fairly reasonable.

Even though the national models differ from each other, the broad structure is common to most models. A typical model is shown in Figure 7.

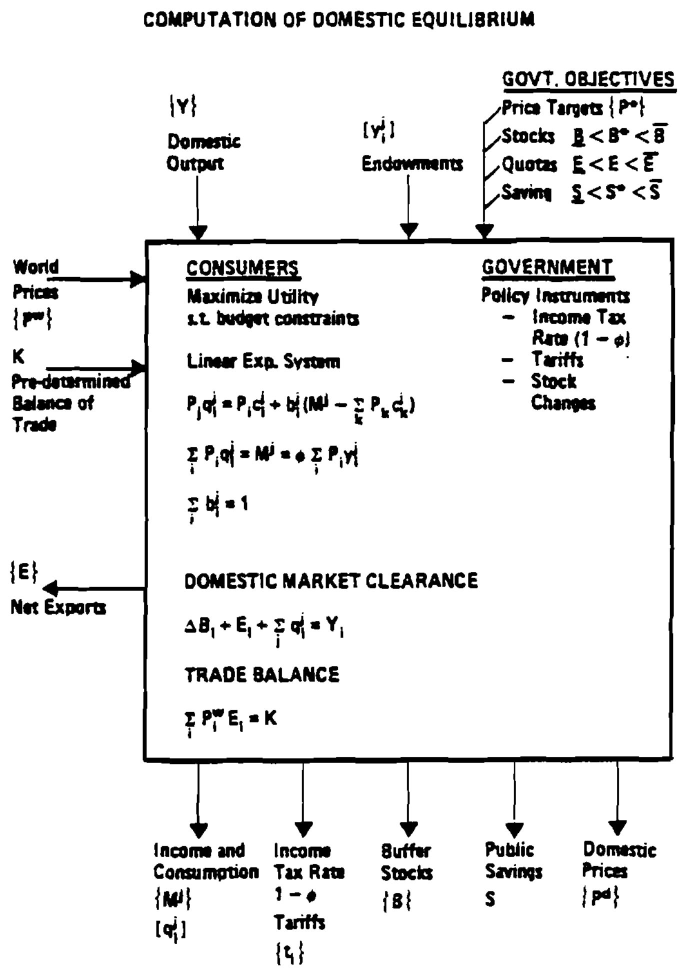
Figure 7.



Past prices and government policies affect production decisions. The domestic production in the n sectors of the economy--$y_1, y_2, \ldots, y_n$ --is then distributed to the various income groups--represented by superscript j. Thus for group j, its share of the national product is given by the vector $y_1^j, y_2^j, y_3^j, \ldots, y_n^j$. What income this share amounts to is determined by the price that these products command. For example, a farmer who has grown 2 tons of wheat and 1 ton of rice would have an income of (2× the price of a ton of wheat plus 1× the price of a ton of rice, minus the cost of producing wheat and rice). The matrix $[y_i^j]^o$ thus describes the initial endowments of the different products for the various groups. Government policies may redistribute these endowments to $[y_i^j]$.

Given these endowments and world prices, the j = 1,...,J income groups trade among themselves under the influence of government policies. The resulting exchange equilibrium determines the domestic prices, the consumption patterns of different income groups, net exports, stocks, tax rates, etc. The details of this computation are given in Figure 8.

Figure 8.



Notes to Figure 8.

Exchange Equilibrium

Given World Prices
Endowments (Note no production during exchange)

Consumers maximize their utilities subject to their Budget constraint

Markets are cleared as affected by Govt. actions

Govt. try to affect the outcome

Tax Rates affect Consumers Budget/Savings

Tariff Rates affect Domestic Prices

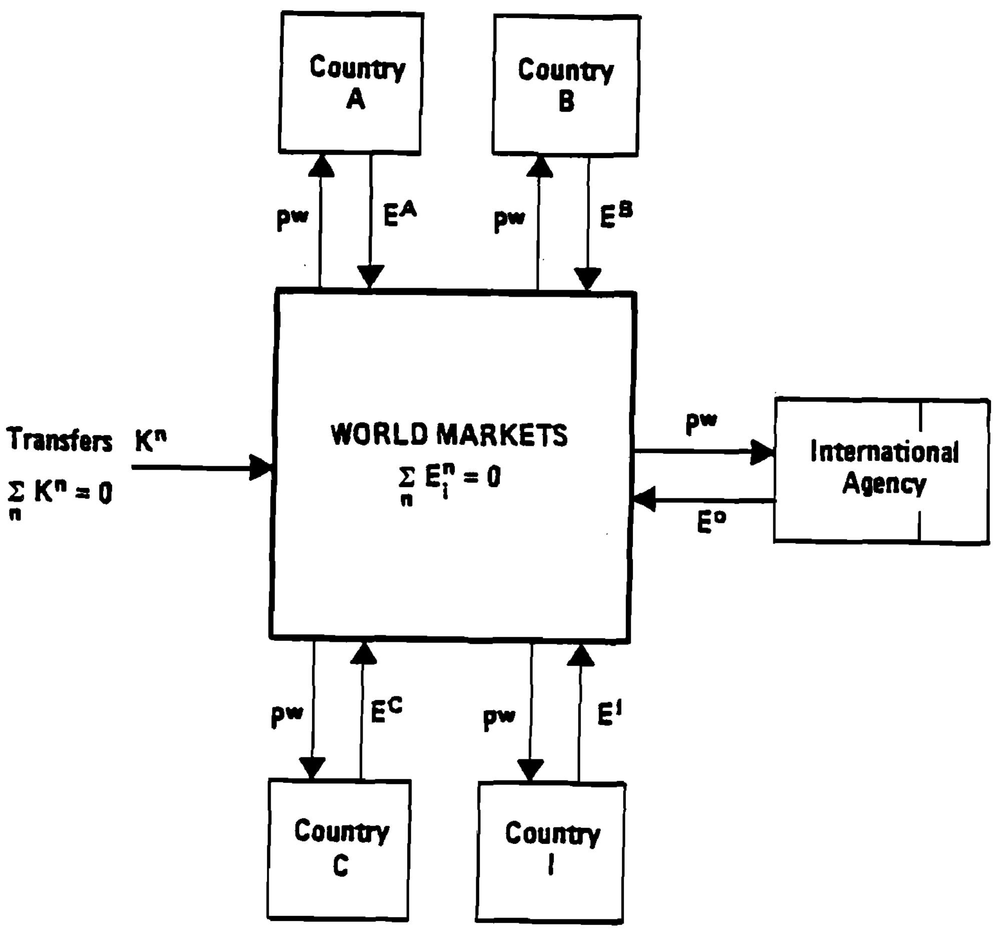
Quotas affect Size of Trade and hence Domestic Availability

Stocks Policy affect Domestic Availability and hence Prices

The net exports of all the countries are thus calculated for a given set of world prices, and market clearance is checked for each commodity. The world prices are revised, and the new domestic equilibria giving new net exports are calculated once again for all countries. This process is repeated until the world markets are cleared in all commodities. The procedure is schematically shown in Figure 9. It may be noted that any international agency—such as a buffer stock agency--can be represented as a country, and the effectiveness of its policies can be evaluated within a framework in which country policies react to the policies of the agency.

FIGURE 9.

INTERNATIONAL LINKAGE



The approach of the FAP model system described briefly above is certainly ambitious, but if the policy issues raised here are to be adequately explored, we believe that such a level of complexity is inescapable.

4. POINT OF DEPARTURE

How does this approach compare with other past efforts? In what way is it different?

We can compare the FAP approach to medium-term agricultural policy analysis on two levels—on the national level and on the international level.

Computable general equilibrium models for national policy analysis are relatively recent. Only a few models are available. The approach in the FAP models differs from these early efforts in some important ways. FAP models put major emphasis on government policies and have a number of agricultural sectors. Moreover, the national models form a part of a linked system of models, thus providing a world setting which determines and responds to individual countries' trade. Thus, the export possibilities of a country are not passively described by export demand functions but are affected by policies of different countries.

Compared with other global models, the FAP analytical approach is different in that it recognizes that there is no world government and that only national governments make national policies. This was also the case with MOIRA, a pioneering effort at introducing this realism into global models. Yet MOIRA had only one aggregated agricultural commodity and had a very limited set of national government policy instruments. In the number of sectors and in the variety of national policies permitted, the FAP system differs from it significantly.

5. IMPLEMENTATION—A NETWORK APPROACH

For one program of an institute of IIASA's size to attempt to build detailed national agricultural policy models for the countries of the world is not a feasible task. Clearly a selection had to be made of the set of countries that we include in our analysis. Fortunately, it is possible to restrict the number of countries to a modest, feasible size and still cover the world agricultural system adequately for the analysis of the policy issues raised.

A selection of 20 countries, including some countries which have common agricultural policies treated as a group, covers nearly 80 percent of the important agricultural attributes of the world such as population, land reflecting potential agricultural productivity, actual production, exports and imports. Most of the remaining countries have individually too small an impact on the international system and can be treated as one group, the rest of the world.

Table 11 gives the list of the countries selected along with data on their importance in the world agricultural system.

Table 11.

1976
PERCENTAGES OF WORLD TOTAL

	POPULATION	PRODUCTION	LAND	IMPORT	EXPORT
USA	5.3	12.3	9.8	8.07	18.85
AUSTRALIA	0.3	1.6	1.3	0.25	5.00
NEW ZEALAND	0.1	0.5	0.1	0.14	2.09
CANADA	0.6	1.2	2.0	1.99	3.25
EC	6.4	11.9	3.3	38.83	26.05
JAPAN	2.8	1.8	0.4	8.36	0.05
AUSTRIA	0.2	0.4	0.1	0.62	0.31
SWEDEN	0.2	0.3	0.2	1.13	0.42
CMEA	9.0	16.7	17.5	12.72	5.74
SUBTOTAL	24.9	46.7	34.7	72.11	61.76
PAKISTAN	1.8	0.9	1.4	0.34	0.34
CHINA	21.4	13.2	17.3	1.64	1.81
NIGERIA	1.6	0.5	1.6	0.50	0.40
ARGENTINA	0.6	2.0	1.7	0.14	2.86
INDONESIA	3.4	1.6	1.5	0.64	1.02
MEXICO	1.5	1.5	1.3	0.35	0.82
THAILAND	1.0	1.1	1.1	0.18	1.23
BRASIL	2.8	4.7	4.0	0.75	5.55
BANGLADESH	1.9	0.7	1.1	0.34	0.11
EGYPT	1.0	0.7	0.3	0.94	0.56
INDIA	15.5	6.7	14.6	1.06	1.30
KENYA	0.3	0.2	0.2	0.06	0.33
SUBTOTAL	52.8	33.8	46.1	6.94	16.33
TOTAL	77.7	80.5	80.8	79.05	78.09

Even so, the development of 20 policy analysis models is still a task which is beyond the means of a single organization like IIASA. Fortunately, IIASA provides a unique opportunity to bring together the efforts of a number of groups and institutions around the world to focus on a common set of problems. It is, however, more difficult to get them to agree to a common methodology and a common approach to these problems. The fact that we have been able to establish a network of participating collaborating institutions which all share our approach gives us confidence that the approach will enhance understanding of national policies and that it is flexible enough to incorporate the specific situations of different countries.

The network of collaborative institutions is shown in Table 12.

Table 12.

PROGRAM PARTICIPANTS

CENTRE FOR WORLD FOOD MARKET RESEARCH, FREE UNIVERSITY, AMSTERDAM

INSTITUTE OF AGRICULTURAL ECONOMICS, UNIVERSITY OF GÖTTINGEN

MICHIGAN STATE UNIVERSITY, EAST LANSING

U.S. DEPARTMENT OF AGRICULTURE, WASHINGTON, D.C.

RESEARCH INSTITUTE FOR ECONOMIC PLANNING, BUDAPEST

INDIAN STATISTICAL INSTITUTE, NEW DELHI

UNIVERSITY OF TSUKUBA, IBARAKI, JAPAN

UNIVERSITY OF NAIROBI, KENYA

SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES, UPPSALA

FINNISH AGRICULTURAL ECONOMICS RESEARCH INSTITUTE, HELSINKI

INSTITUTE OF AGRICULTURAL ECONOMY, WARSAW

SYSTEMS RESEARCH INSTITUTE, WARSAW

INSTITUTE FOR AGRICULTURAL ECONOMICS, AUSTRIA

AGRICULTURE CANADA, OTTAWA

The working of the collaboration between the institutions and the FAP group of IIASA is complementary, and brings benefits to all participants.

The FAP group at IIASA started out with the development of the methodology of linking the country models together as well as the methodology of computation of domestic equilibrium under the influence of government policies. Simultaneously a few country case studies were begun. The interaction of these two activities enriched the results of both. The national models have become more rigorous in conception, and the linkage and equilibrium algorithms permit more realistic policy options.

Subsequently the FAP group also developed a simplified model system consisting of models of all the selected countries based on a data bank organized at IIASA around data obtained from international organizations. All the different simplified national models have a common structure, and they do not include many country-specific policies. The development of the simplified system of models served two very useful purposes:

(a) It demonstrated the feasibility of linking various national models.

(b) It established the computational efficiency of the algorithms developed.

The simplified national models were further developed with the help of specialists from various countries into an intermediate version of models which constitute a system called the ***basic linked system***. It was necessary to do this for two reasons:

(a) It provides a background system for running an individual national model when it is ready without waiting for the completion of all national models.

(b) It permits analysis of some selected issues of international policies and provides experience in policy analysis using the linked system.

The FAP group at IIASA provides its collaborative institutions access to its computational algorithms, its basic system of simplified national models and its data banks. Moreover, there is also available at IIASA the accumulated experience in building policy models which can substantially reduce the time required to construct a detailed national model.

The collaborating institutions, on the other hand, bring knowledge and the expertise about specific countries and put in considerable manpower of their own in developing the national models, which thus become more realistic. Moreover, they serve as contact and dissemination points for national decision makers and serve to ensure that the work of FAP will find real-life applications.

The present status of the work on the detailed national models is summarized in Table 13.

Table 13.

DETAILED NATIONAL MODELS*

Completed and Applied	Nearly Completed	Well Under-Way	Scheduled to Start
• Hungary	• India	• Egypt	• Australia
• CMEA	• EC	• USA	• New Zealand
	• Brazil	• Poland	• Mexico
	• Kenya	• Austria	• Nigeria
	• Sweden	• Japan	• Pakistan
		• Finland	• Argentina
		• Canada	
		• China	
	**Thailand	**Bangladesh	**Indonesia

*Status as of February 1981

**Coordinated by Centre for World Food Studies, Amsterdam

The establishment of this network of an international research community all sharing a common approach to food and agricultural policy analysis is a significant achievement of the program, an achievement which could not have been brought about except by an institute like IIASA.

* * *

Task 2: TECHNOLOGICAL TRANSFORMATIONS in Agriculture: Resource Limitations and Environmental Consequences

6. THE FOOD PROBLEM – FUTURE BUT NOT FAR

From a longer term perspective the food problem acquires added dimensions; and questions of availability of resources to produce adequate food, efficiency of techniques, and environmental consequences come to the fore. One can perceive certain trends:

(a) *Land will have to be cultivated with much greater intensity than at present.*

The pressure on land will arise from the increasing population, which with increasing income would want to consume more food and more animal proteins. The various projections made for the year 2000 give a clear indication of this. Table 14 shows the effect of increasing population as projected by *The Global 2000 Report to the President.*

Table 14. ARABLE AREA PER CAPITA, ACTUAL AND PROJECTED (ALTERNATIVE I)

	1951-55	1971-75	1985	2000
Industrialized Countries	.61	.55	.50	.46
Western Europe	.33	.26	.24	.22
Centrally Planned Countries	.45	.35	.30	.26
China	.19	.16	.13	.11
Developing Countries	.45	.35	.27	.19
World	.48	.39	.32	.25

Note: Double crop area counted only once, includes temporary crops, current fallows, pastures and kitchen gardens.
Source: *The Global Report to the President*, Vol. 2, Table 6-13, p. 99.

The normative scenario of the FAO's AT 2000 given in Table 7 show a similar picture. By the year 2000 more than 60 percent of the population in the developing countries is projected to be living in countries where no scope exists for further expansion of arable area. Similarly, increases in yields of more than 60 percent are projected between 1980 and 2000. All of these will call for intensification of cultivation of land.

(b) *The increases in inputs required to raise yields will be significant, and the costs of some of the inputs will rise substantially. Not only is arable land use likely to reach its potential limits, but water needs may near the exploitable upper limits as well.*

The pressure on water resources will arise mainly from the fact that water resources are limited; and as irrigation development proceeds to the limits of irrigation potential, water will become more scarce and more expensive. This would be further accentuated by higher industrial use--such as for power generation--as well as higher demand due to increased urbanization and the improved sanitation standards of the growing population of the developing countries.

The FAO normative scenario projections for irrigation needs are shown in Table 15. The required increases in the use of fertilizers are also indicated in Table 15.

Table 15. PROJECTED IRRIGATION AND FERTILIZER NEEDS OF DEVELPING COUNTRIES: FAO'S AT 2000 – NORMATIVE SCENARIO.

	1980	2000
Irrigation		
Potential irrigable land (10^6 Ha)	394	394
Area equipped for irrigation (10^6 Ha)	104	152
Percent area fully equipped for irrigation	60	77
Fertilizers		
Total nutrients (10^6 tons)	*19*	*94*
Kg of nutrients/hectare	*26*	*100*
Kg of nutrients/hectare for fully irrigated land	*70*	*320*

Source: *Agriculture: Toward 2000.* FAO, c79/24, July, 1979.

(c) *As the basic agricultural resources- - land, water, and fertilizer- - become more scarce and more expensive, a technological transformation of agriculture will have to take place. The required higher yields and changes in the relative prices of land, water, fertilizer, and other factors and inputs required for agricultural production will clearly lead to changes in the techniques of production.*

Table 16 shows the growing importance of water demand for industrial and urban uses.

Table 16. ESTIMATES OF WORLD WATER USE PATTERN

	Fraction of Total Water Use in Percent	
	1967	2000
Agriculture	73	53
Domestic	5	6
Industry and Mining	22	41

Source: *The Global 2000 Report*, Table 9-5.

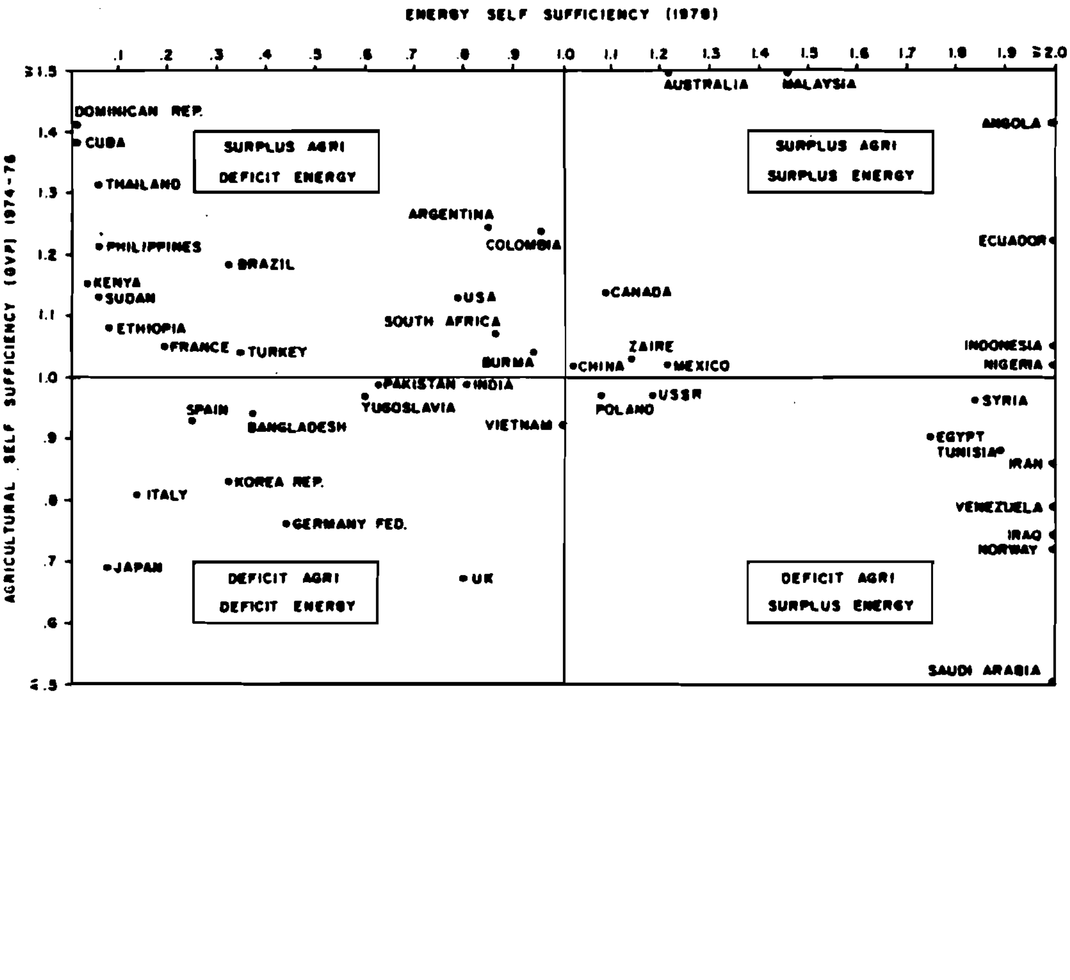
Development of water resources becomes increasingly expensive, as the more accessible and easier-to-exploit sites are developed first. Similarly, fertilizers are also likely to become more expensive in real terms in the future, as prices of fertilizer feed stocks, the most widely used being naphtha, are likely to rise with energy prices.

A significant intensification of inputs is indicated by a look at the year 2000, which is only 20 years ahead. A perspective beyond 2000 would call for ever greater intensification.

(d) *Increasingly expensive and uncertain energy supply will on the one hand increase the pressure on land and on the other hand make it harder to obtain higher yield through conventional techniques.*

Expensive energy not only makes fertilizer and lift irrigation expensive but also tempts food-surplus energy-deficient countries to divert their land to energy plantations. Figure 10 shows a plot of countries according to their energy and agricultural self-sufficiency. The countries in the left top group are the ones likely to turn to energy plantations. Since these include the major food exporters of today (U.S., Argentina, Brazil, *et al.*), a large-scale adoption of alcohol programs by these countries could have profound implications for other countries and for the world food system. It would mean that others would have to get even higher yields from their land.

Figure 10. Energy and Agricultural Self Sufficiency.



Source: *Background Paper for Discussions, FAO Expert Consultations on Energy Cropping Versus Food Products*, Rome, 2-6 June, 1980.

(e) *Past estimates of ultimate food production potential indicate more than adequate potential, but these estimates have not fully accounted for environmental consequences and feedbacks in land productivity.*

Table 17 summarizes some of the estimates made of the world's ultimate production capacity. Though the estimates show a wide range, the lowest shows adequate potential to feed more than 8 billion people, and the highest one goes as high as 150 billion. Some of these estimates do not account for environmental feedback, which may bring into question the sustainability of techniques of production implied by these estimates.

Table 17. The World's Food Resources Converted to Estimates of the Numbers of People Who Can Be Fed By Them.

Study made by	Billions of people
University of California	8
R. Revelle	38–48
J. Klatzman	10–12
C. Clark	45–150
H. Linnemann *et al.*	90

Sources: University of California. 1974. *A Hungry World: The Challenge to Agriculture*. Summary Report of a University of California Task Force Meeting. Los Angeles.
Revelle, R. 1974. Food and population. *Scientific American* 231(3):160.
Klatzman, J. 1975. *Nourrir Dix Milliards d'Hommes*? Paris: Presses Universitaires de France.
Clark,C. 1967. *Population Growth and Land Use*. London: MacMillan.
Linnemann, H., J. de Hoogh, M.A. Keyzer, and H.D.J. van Heemst. 1977. *MOIRA: Food for a Growing Population*. CP-77-1. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Table 18 shows the importance of introducing environmental considerations into such estimates. It shows the regions of Africa which can meet their projected food needs through national production in 2000 with and without environmental feedbacks. It can be seen that with the present crop mix and intermediate level of inputs the number of countries unable to meet their food needs when various conservation measures are taken to maintain present fertility levels is 13. In the absence of such measures this number rises to 17.

Table 18. NUMBER OF CRITICAL/DANGER COUNTRIES AT YEAR 2000. Projected Population > Assessed Potential Population Supporting Capacity.

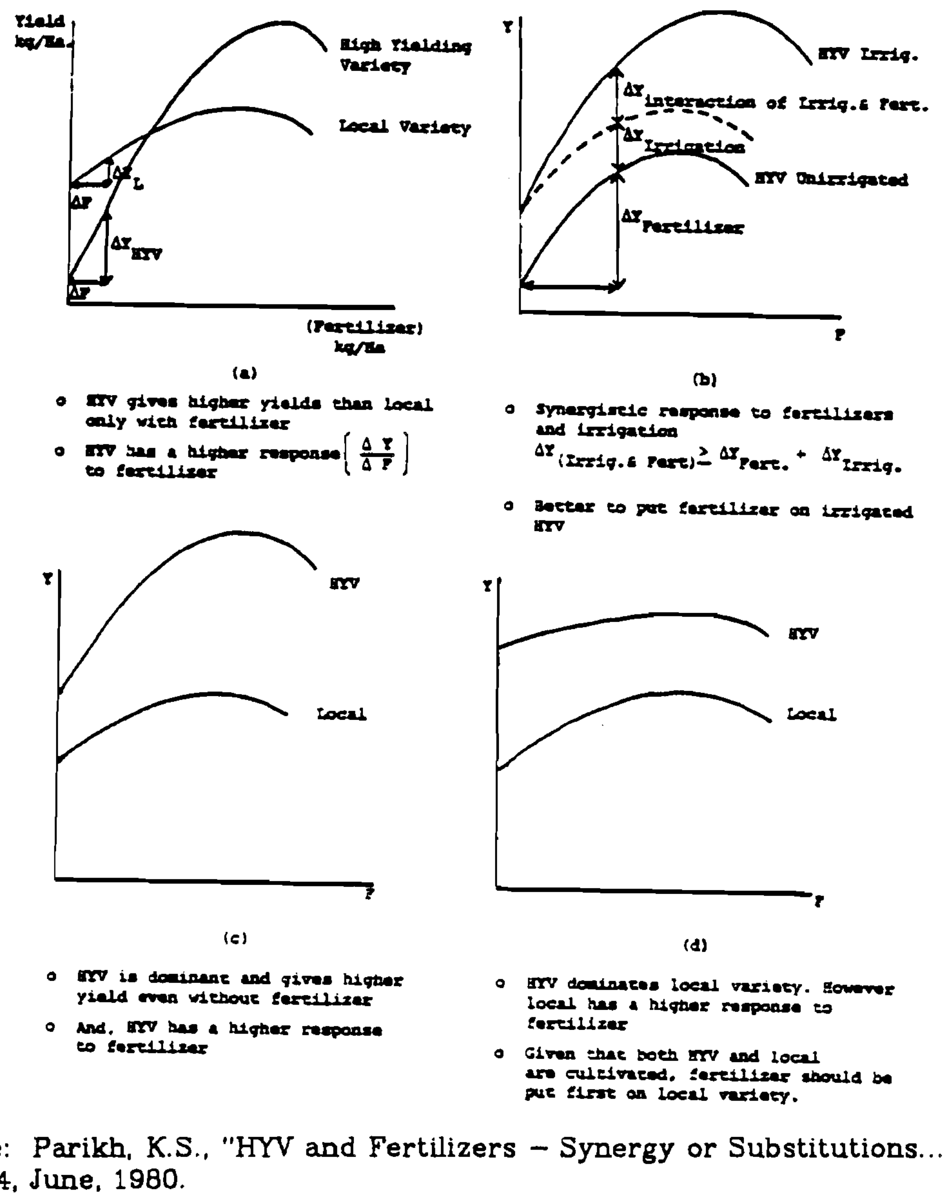
	With Present Crop Mix	With Improved* Crop Mix
A. Low Level of Inputs		
No conservation measures	34	30
With conservation measures	27	23
B. Int. Level of Inputs		
No conservation measurs	17	12
With conservation measures	13	10
C. High Level of Inputs		
No conservation measures	12	11
With conservation measures	8	5**

* Which maximizes calorie production subject to protein constraint.
** Countries such as Djibuti, Cape Verde, Lesotho, Rwanda, and Western Sahara, which have very little arable land so that not much can be done by them.
Source: "Second Consultation – Land Resources for Populations of the Future," Rome, 1979, FAO/UNFPA Projct FPA/INT/513 in collaboration with the Food and Agriculture Programme, IIASA.

(f) *A choice of agricultural production techniques offers alternatives not only for intensive vs. extensive cultivation but also of intensification of various inputs such as fertilizer and water. Understanding the nature of technology is critical for formulating appropriate policies for promoting adoption and development of appropriate techniques.*

The policy implications of the nature of technology can be illustrated by an examination of the new high yielding varieties (HYV) as shown in Figure 11.

Figure 11. Policy Implications of Nature of Yield Responses.



Source: Parikh, K.S., "HYV and Fertilizers – Synergy or Substitutions...", IIASA, PP-80-4, June, 1980.

What we conclude from the foregoing is that over the coming decades a technological transformation of agriculture will take place which will be constrained by resource limitations and whose environmental implications pose questions regarding the sustainability of adequate production to feed mankind in the future.

7. ISSUES AND APPROACH

As we anticipate over the coming decades a technological transformation of agriculture which will be constrained by resource limitations and which could have serious environmental consequences, a number of important questions arise.

(a) What is the stable, sustainable production potential of the world? of regions? of nations?

(b) Can mankind be fed adequately by this stable, sustainable production potential?

(c) What alternative transition paths are available to reach desireable levels of this production potential?

(d) What are sustainable, efficient combinations of techniques of food production?

(e) What are the resource requirements of such techniques?

(f) What are the policy implications at national, regional and global levels of sustainability?

Stability and sustainability are both desireable properties from the considerations of inter-generational equity as well as of political stability and peace.

We hold environmental considerations to be of critical importance in answering the questions posed.

Ideally, to be aesthetically consistent with our approach to shortrun strategies, Task 1, a general equilibrium approach may be desireable. Such models exist in economics literature, and it has also been shown that solutions exist under certain restrictions which require, among other things, that consumers utility functions include public goods and that markets for externalities created by environmental consequences of production exist. Such an approach is, however, empirically not feasible.

Since we desire a long-term perspective here, a descriptive approach poses many difficulties. What we chose to do is to identify the broad dimensions of the problem and to obtain general policy guidelines. For this purpose a planning, optimizing model to identify efficient paths is desireable. Since quantitaive knowledge of environment processes is not very well developed in the literature, we will have to include a great deal of detail to specify a meaningful problem. This will make the programming model very large, and only a linear programming (LP) model is likely to be practical. However, the environmental feedback processes are highly nonlinear and may not permit linearization. This would then lead us to an approach based on a recursive LP model.

A conceptual model framework is shown in Table 19. The model shown can be used for a nation or for a subregion in a nation. Given the prices at which the region can trade externally, its domestic prices and domestic rquirements, those agricultural activities are to be selected which would maximize net income from agriculture subject to certain constraints. Among these are included a sustainability constraint as well as environmental feedback relations.

Table 19.

TECHNOLOGICAL TRANSFORMATION OF AGRICULTURE
ANALYTICAL FRAMEWORK – CONCEPT

Given $\{\bar{P}_i^w(t)\}$ Trade Prices

$\{\bar{R}_i(t)\}$ Regional Requirements and

Resource Base $\{A_f^z(o)\}$ Area in zone z fertility class f

$\{K(o)\}$ Fixed capital stock

Find Activity Intensities $\{x(t)\}$ which

Maximize profits at trade prices
less cost of external effects

Meet domestic requirements and
which are sustainable

Maximize $$\sum_t \frac{1}{(1+\phi)^t} \sum_i \left[\left(P_i^w(t)\,E_i(t) + P_i^w(t)\,R_i(t) - P_i^w(t)\,Y_i(t)\right) - C_t(B_t, B_{t-1}, \ldots)\right]$$

s.t. Inputs / Bads $$\begin{Bmatrix} Y(t) \\ B(t) \end{Bmatrix} = \left[a(t)\right]\{x(t)\}$$

Resource Limits	$\{x(t)\} \leqslant \{A_f^z(t)\}$
Output Levels	$\{Q(t)\} = [u]\,\{x(t)\}$
Sustainability	$\{Q(t)\} \geqslant \{Q(t-1)\}$
Demand	$\{Q(t)\} \geqslant \{\bar{R}(t)\} + \{E(t)\}$
Feedback of Bads	$[a(t)] = f[A_f^z(t-1)]$
	$\{A_f^z(t)\} = g[A_f^z(t-1), B(t)]$

8. POINT OF DEPARTURE

Our program approach is different from past approaches in that we hope to take into account both environmental feedbacks and economic considerations in an integrated framework.

In addition we will carry out a number of case studies which will help in validating our approach and in understanding the complexity of the system. The case studies would be so selected as to represent various agricultural and economic organizational systems. We will also obtain a global perspective.

Finally, the results of this task will feedback into the shortrun strategy analysis models of Task 1, and modifications of medium-term policies from long-term considerations of sustainability would be obtained.

9. IMPLEMENTATION

The various elements that have to be worked on are as follows:

(a) *Description of existing technologies:* Quantitative descriptions of production processes for crop production, livestock production and food prcessing will be needed. In addition to the conventional description of inputs of production processes in our activity analysis framework, associated environmental bads or goods which come as joint products would have to be quantified.

(b) *Environmental feedbacks:* The process level environmental bads would have to be aggregated to obtain region level effects. These effects would have to be further translated into their impacts on the quality of the resource base for the next period. For example, how soil erosion changes fertility of soil from one period to the next would have to be quantified.

(c) *Detailed anaytical framework and computer software:* These will be developed at IIASA.

(d) *Country case studies:* At present (November, 1980), the countries or regions within countries being considered for case studies are: Hungary, CSSR, USA, USSR, Italy, Japan, Kenya, and Thailand.

(e) *Global perspective:* An integrated perspective will have to be formed from the case studies and supplemental analysis.

As in our Task 1, we will follow here a network approach, especially for carrying out different country case studies.

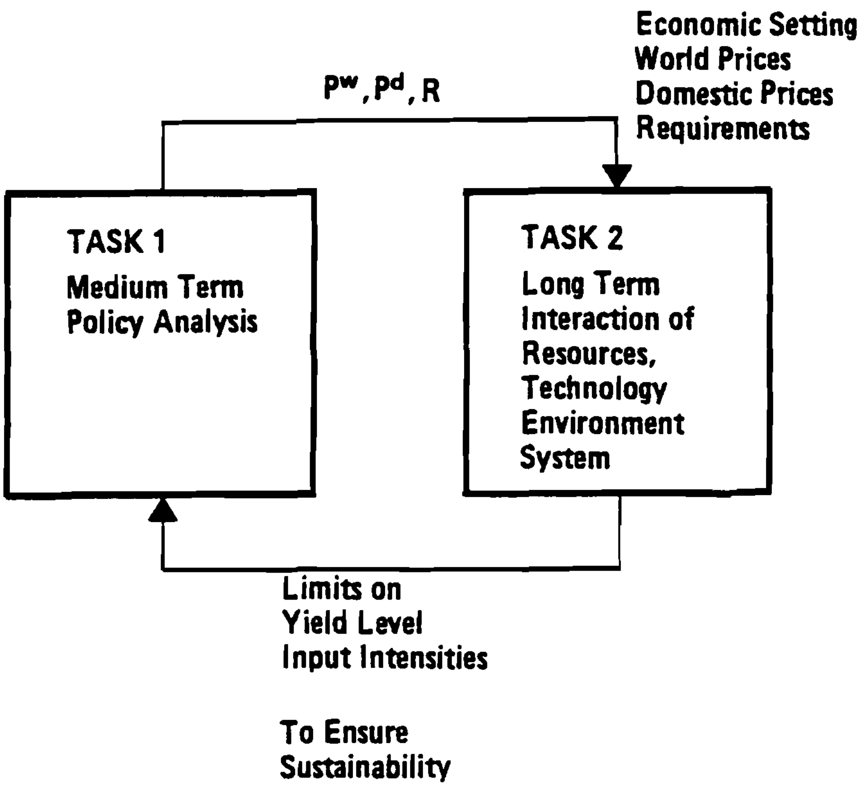
* * *

10. CONNECTIONS BETWEEN TASKS OF FAP

The two tasks are viewed as complementary. Both are essential to have a real understanding of the food and agricultural systems. Figure 12 shows this connection.

Figure 12.

CONNECTION BETWEEN TASKS OF FAP



The findings of Task 1 will provide a starting point for the scenarios of Task 2, providing a realistic basis for long-run investigations. The findings of Task 2 might modify the representations of permissible intensities of technologies in Task 1. Present policies and actions may have to be constrained to keep open options for technological transformations in later decades.