FOOD FOR ALL IN A SUSTAINABLE WORLD:

The IIASA Food and Agriculture Program

Summarizing presentations at the IIASA Food and Agriculture Program
Status Report Conference, February 1981

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Editors

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FOREWORD

It is the custom for a major multiyear research program at the International Institute for Applied Systems Analysis to organize a conference at the midpoint of its work in order to review its status.

The Food and Agriculture Program, which began in 1977, was approved by IIASA's Council as a research program for a period of five years and has since been extended until the end of 1984. It therefore organized a status report conference in February 1981 to communicate the research results obtained so far, to describe present activities, and to consider what topics should be emphasized in the future research of the program. This report summarizes the material presented at the conference.

IIASA's exploratory activities in the food and agricultural area were prompted by concern for the problems of inadequate food availability in the world. Its focus has been on obtaining an understanding of the possible policies, national and international, of surplus and deficit countries, of developed and developing countries, so as to be able to identify policies to alleviate current food problems and to prevent future ones.

It is our hope that this report will extend understanding of the goals and activities of the Food and Agriculture Program and broaden the international network of people and institutions collaborating in our work and making use of our results.

ROGER LEVIEN
Director
International Institute for
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PREFACE

In February 1981, halfway through its research program planned for 1977 to 1984, the IIASA Food and Agriculture Program (FAP) held a conference to review the current status of its work, to describe the results obtained so far, and to sketch the direction of future work. This report summarizes the presentations at the conference.

The focus of the FAP's activities has been toward obtaining an understanding of national and international policy options to alleviate present food problems and to prevent future ones. We see the present food problem as one of the inadequate availability of food due to improper distribution and insufficient production. We seek a realistic understanding of policy options in the context of a world of interdependent sovereign nations pursuing their own objectives. Thus the positions of all countries are important, whether surplus or deficit, exporting or importing, developed or developing. On the other hand, we see the long-term food problem as one of identifying alternative forms of technological transformations of agriculture that can lead to a sustainable, resilient and equitable world able to feed its growing population. In Part 1 we describe in detail the problems the FAP perceives, the issues it addresses, the goals it is aiming at, and the approaches it is following.

In its early years, the FAP placed a major emphasis on methodological work that would permit satisfactory evaluations of national and international policy strategies in an interdependent world. Among our significant achievements are, we believe, the development of the international linkage system and its methodological formulations, the development of efficient algorithms and computer software for national and international equilibrium computations, and a set of "simplified" national models for some 23 selected countries that represent 80% of the important attributes of the world food system. This work, along with a related game-theoretic approach, is described in Part 2. The first version of the simplified national models, based mainly on published international data organized in a computerized data bank described briefly in Part 3, had a common structure for all the countries and a relatively limited set of policy options. It served the very useful purpose of demonstrating the feasibility of our approach.

However, for many important national policy analyses the simplified models are inadequate, and one needs detailed models describing the country's economic structure, resource base, and the institutional framework for policy formulation. We hope to have as many detailed models of our selected countries as possible. The detailed national models constitute the most critical elements of our approach, and a major part of our resources has consequently been allocated for their development. The work on developing these models is at various stages: some are complete, some are nearing completion, and others are still in the initial stages. Though work on some has mainly been carried out at IIASA, others are largely being constructed by collaborating institutions. We prefer to build these models as far as possible with the help of the eventual users of the models in the country, and in many cases this has been done. Thus, we are assured that they would be useful in actual decision making processes. The various national models are described briefly in Part 4 (the lengths of the papers do not reflect the stages of development but rather the expository styles of their authors).

As various detailed national models become ready, we shall carry out national policy analysis in the context of an international environment of trade and policy responses of other countries. To provide this background and to evaluate a number of international policies, we are developing our linked system of simplified models further into what we call a ***basic linked system***. Each model of this system will be either a version of the detailed national model built by the group building the detailed model or a version of the simplified model evolved with the help of experts from the country concerned. Much of this basic linked system is expected to be complete by the end of 1981.

In contrast to our task on short-term strategies, the work of our task on the long-term problems of agriculture, its resource limitations and environmental consequences, started relatively recently. Thus even our methodological work is not completed, and our approaches remain somewhat tentative. In fact, the complexity of the interactions of the resources, technology, and environmental aspects of agriculture is such that developing an operational analytical framework itself constitutes a significant methodological contribution. Since methodological developments are spurred by the context of substantive problems, we have initiated a number of case studies, again with the help of collaborating institutions. Since the problems of increasing prices of energy and its unpredictable availability are expected to affect agricultural technologies, work has also been started on energy–agriculture interactions. Part 5 describes our work on this task.

The purpose of this midcourse status report conference was as much to get critical comments as to present a review of our work. The last session of the conference was, therefore, devoted to comments from the participants. These are summarized in Part 6. We are thankful to those who commented at this session.

The accomplishment of the FAP's ambitious research objectives is being sought through a unique network of collaborating institutions around the world, all working toward shared objectives. This network is possible only because IIASA exists. The total effort expended by the collaborating institutions has exceeded that expended by the FAP at IIASA. Thus, this status report describes the work of the entire collaborating network. We are grateful to its members for their enthusiastic participation in the conference and their prompt responses to our request for summaries of their presentations for this status report.

The organization of the status report conference and the preparation of this report have required the work of people too numerous to mention. To all of them, and to the conference participants, we express our sincere thanks.

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*The Food and Agriculture Program began under the leadership of Professor Ferenc Rabár, who returned to Hungary in mid-1980. Professor Kirit Parikh, who was the Acting Program Leader from May 1980, became Program Leader in July 1981.

CONTENTS

PART 1. FOOD PROBLEMS AND POLICIES: PRESENT AND FUTURE, LOCAL AND GLOBAL

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1.1. Genesis

Food problems – efficient production or procurement of food and the appropriate distribution of food among members of family and society – are endemic problems of mankind. Yet the nature and dimensions of these problems have been changing over time. As economic systems have developed, specialization has increased; and this has led to increased interdependences 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 this growing interdependence of nations, reflected in increasing volumes of food trade, and this requires that the exploration of national policy alternatives be carried out in the context of international trade, aid, and capital flows.

When we began our research in the field of food and agriculture in 1976, we started with these objectives:

- 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 food problems in the future

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 qualified as follows:

- 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 a global population that may double by 2030.

To realize these objectives the FAP is organized around two major tasks: Task 1, termed "Strategies: National Policy Models for Food and Agriculture," in which the present short-term problems of policy are explored, and Task 2, "Technological Transformations in Agriculture: Resource Limitations and Environmental Consequences," in which the questions raised by a long-term perspective are investigated.

We describe Task 1 in section 1.2, Task 2 in section 1.3, and the complementary nature of these two tasks in section 1.4. In considering each task in the subsections we describe the following: the problems as we perceive them; the specific policy issues addressed; an outline of the approach considered appropriate for addressing the issues; how the FAP approach is different from other, past efforts; the network approach of collaborating institutions followed for implementation of the program; and the status of the work.

1.2. Task 1: Strategies: National Policy Models for Food and Agriculture

1.2.1. 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?

The starting point for our work was the 1974 Conference of the Food and Agriculture Organization of the United Nations (FAO), at which it was stated that there were about 462 million hungry people, mainly in developing countries but also in developed countries. This was a shocking – and at the same time controversial – number. However, if we look at the recent estimates shown in Table 1, especially those made by the FAO in its study of agriculture toward the year 2000 (FAO, 1979) and those set forth by the Organization for Economic Co-operation and Development (OECD, 1979), we see that the number of hungry people, even by the year 2000, could be 242 or 350 million, according to which projection is accepted.

Thus, hunger appears to be a stubborn problem. An optimist approaches the problem from a favorable point of view: the estimates seem to say that the proportion of the population undernourished will decline from 16% possibly to 7% by the end of the century. However, this positive view is hard to sustain in the light of the figures showing the amount of grain needed annually to eradicate hunger: 32 million tons in one estimate, 20 million tons in another. From the technical side the problem is marginal. But it is hardly marginal to those who are hungry: for them it is a matter of life and death.

Against this background, in our early work we wanted to achieve a problem definition as a framework for our research that would be as close to the realities as possible.

We began with a set of perceptions:

(1) 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 average, because of the improper distributions of incomes and food. (See Appendix a, sections 1, 2 and 3, at the end of Part 1.)

TABLE 1 Recent estimates of the number of undernourished people in the world.

Year: Source	Number of undernourished people, in millions (% of population)	Grain equivalent needed to eradicate hunger, in millions of tons
1970: FAO, 1974	462 (16)[b]	a
1980: The World Bank, 1980	780[d]	a
2000: (1963–75 trend rates) FAO, 1979	387 (11)[c]	32
2000: (normative growth) FAO, 1979	242 (7)[c]	20
2000: OECD, 1979	350[c]	a
2000: US Presidential Commission on World Hunger, 1979	a	32

[a] No statistics given.
[b] Excluding centrally planned economies of Asia.
[c] Developing countries excluding China.
[d] Developing countries excluding China and other centrally planned economies.

(2) National policies are the most important policies in dealing with the problem of hunger, through increased production and/or through more equitable distribution. (See Appendix a, sections 4 and 5, at the end of Part 1.)

(3) Though national governments are the paramount 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 sizable part of the total trade of many countries, and these countries are affected by the policies of other countries. (See Appendix a, section 6, at the end of Part 1.)

(4) The inherent uncertainty in agricultural production implies that even countries that are normally self-sufficient may need to depend on trade in exceptional years. (See Appendix a, section 7, at the end of Part 1.)

(5) 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 a given country we can identify the resources, the technologies (which depend on the country's stage of development), the sectoral relations (different from country to country), the decision makers (those who initiate and carry through policies), and the economic settings (within which policies can be set). However, our detailed knowledge of what goes on inside the country is in stark contrast with our lack of knowledge of what goes on beyond its borders. The agricultural policy of a country has side effects, and these side effects have uncalculated influences on other countries. Other countries react to these influences in uncalculated ways. These reactions in turn produce unexpected influences on the originating country, as well as others. In sum, these intercountry interactions produce myriad effects.

Thus, our understanding of the system is fuzzy, and it is made more so by the shifts that the system exhibits.

- Sectoral shifts. As an example, we know that the energy price changes in 1973 caused price rises in fertilizer and in fuel for well pumps that resulted, according to some experts, in a shortage of as much as 15 million tons of grain. Changes in infrastructure have an important impact on food distribution. However, agricultural production is the basis for developing rural industries. Thus, changes in other sectors greatly affect agricultural production, which in turn induces changes in other sectors.
- Spatial shifts. We know that droughts have effects, not only where they occur, but also elsewhere. We know that agricultural policies made in one country often have important effects in others.
- Temporal shifts. An energy price change may have an effect on the harvest of the next year only, but this will affect feed prices, raising the prices of meat in the following years, and so on.

If we take into consideration that all of these shifts combine in the actual international food system, we can agree that the local and global effects are difficult to separate.

It is within this fuzzy and highly complex system that we try to solve the food problem, which we identify as a problem of inadequate food provision for a large number of people as a result of insufficient income and improper distribution, which is exacerbated by uncertain climatic conditions, and which is amenable mainly only to national policies that 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 one another.

1.2.2. Goals, issues, policies

The goals of our task on strategies are:

(1) to provide a nation-specific decision making tool to analyze policies

(2) to investigate the consistency of policies, since agricultural policies have many objectives, and policy instruments, if combined, can lead to unexpected results

(3) to study the national policies of countries in an international framework

(4) to study international policies in a world whose national governments' policies are formulated in pursuit of their own national goals

In the short term, we shall investigate the system to see where we should expect tensions, pressures, and problems in the future. Which countries cannot grow as they should owing to food and agriculture problems? What are the causes of these effects? Can international policies help?

Four possible environments – market types – in which international policies could be conceived are given in the following.

(1) The present market remains unchanged. In such a case, what are the chances for specific developing countries to enter the market?

(2) The market is assumed to be liberal. The consequences of such a market present questions that are far from trivial. Some studies say that if we liberalize the market it could, for instance, help farmers in the US and consumers in Europe, but it would not change the situation for the developing countries. Such statements can be checked only by means of a consistent set of models capable of following these assumed policies through to their consequences.

(3) The market is regulated, in the sense that it is influenced deliberately in the interests of the developing countries. The concept of such a new economic order underlies many of the proposals of the United Nations Conference on Trade and Development, international agreements like the Lomé Convention, and various commodity agreements. We should like to see who is gaining and who is losing, and how the burden is being distributed among the participants.

(4) The market is directed toward self-sufficiency. Which developing countries can be self-sufficient? How far can the others proceed toward self-sufficiency? If some individual countries cannot become self-sufficient, are there groups of countries that can?

To be more specific we list below some of the important policy questions that need to be explored.

National Policies

For growth:

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

(2) What are the impacts of the development of irrigation on production, prices and consumption?

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

(4) What is a desirable rate for the introduction of advanced technology and mechanization?

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

For equity:

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

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

(8) 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?

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

(10) How do changes in landholding patterns and in tenancy structure affect production and consumption?

For stability:

(11) Is price stabilization desirable? Do stable prices benefit producers?

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

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

For self-sufficiency:

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

(15) What are effective ways of utilizing food aid? Which is more effective – food aid or general aid?

(16) 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

(1) The adoption of large-scale programs for alcohol production/energy plantations by energy-deficient countries with food surpluses.

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

(3) An agreement to keep world market prices at given levels by adjusting internal prices, either for all nations or for a subset of nations.

(4) The interpretation of such an agreement as a compensatory finance scheme in which developing nations are indemnified against adverse developments on the world market.

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

(6) The establishment of international food transfers of the size required to banish hunger within a prescribed time limit.

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 2 summarizes the possible impacts of some important policies on these objectives in a large developing country such as India.

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 is indeterminate, as is shown in the last row of Table 2. Faced with a food shortage, a country may decide not to accept food aid

TABLE 2 Effects on objectives of various policy instruments.

Policy Instrument	Objective: Growth	Equity	Stability	Sustain-ability
Investment level	↑	↑ ↓	↓	
Income tax	?	↑ ?		
Indirect tax	↑	↓	↓	
Irrigation	↑	↓	↑	↓
High yield varieties	↑	↓	↓ ?	↓
Fertilizers	↑	↑ ↓		↓
Mechanization	↑ ?	↓		
Land ceiling and redistribution	↑ ↓	↑		↑ ↓
Tenancy reforms	↑	↑		↑ ? ↓
Public food distribution	↓	↑	↑	↑
Procurement of food grains	↓	↑		
Buffer stock operation	↓ ?		↑	↑
Food aid	↑ ↓ ?	↑	↑	↓

↑ Furthers objective.
↓ Adverse effect on objective.
? Questionable effect.

but to ration food to deal with the deficit. In such a case the unsatisfied demand for food from those who could afford to buy more would be redirected toward consumption of other goods, which may reduce exports of these goods and lead to reductions in investment and food output in the future. However, were the country to accept food aid and distribute it only to the poor at subsidized prices, it would improve their well-being but have little or no impact on market prices and no impact on future output. It is difficult to identify the poor though, and the food might be distributed to all citizens living in given areas – mostly urban areas. This would lower market prices of food, reduce farmers' incentives to produce, and might lead to lower future output. But if the food aid constitutes an additional aid, it would permit the government to promote increased investment. If the government does in fact increase investment, this could, if directed to agriculture, give a higher output in the future. The outcome in a particular instance would thus depend on the totality of government policies.

Thus to evaluate policies we need a policy analysis framework, or a model, which can help determine quantitatively the impact of policies on various objectives, as shown in Fig. 1. Only then can we evaluate alternative policies. In other words, a quantitative systems analytic framework – a general equilibrium approach – is needed.

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 specific policy instruments can be identified with particular policy makers, and to include the reactions of various

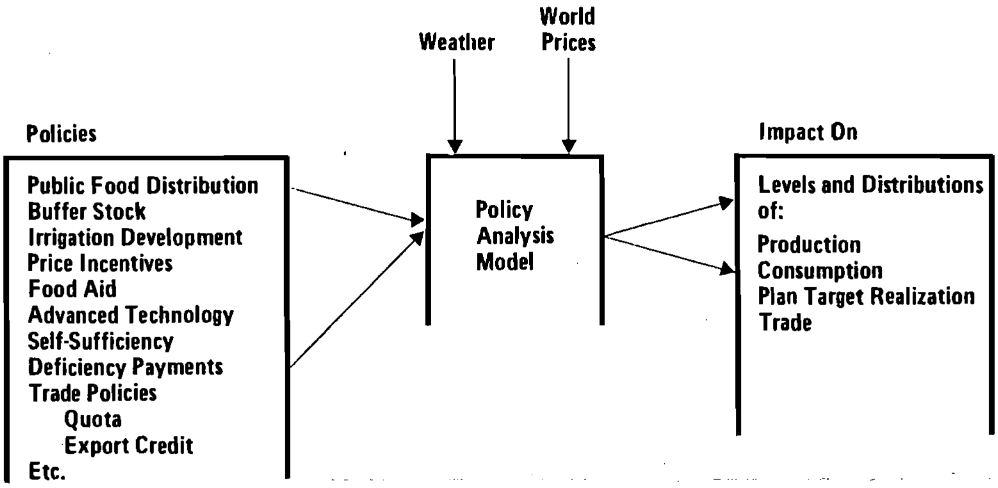


FIGURE 1 National policy analysis framework.

economic agents to such policies. Moreover, normative analyses often imply institutional transformations of the socioeconomic framework, which are not easy to bring about in the 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 by trade, aid, and capital flows.

The FAP model system is characterized as follows:

- it is price endogenous;
- it is descriptive;
- it includes national models
- of open exchange economies,
- with government policies for
- year by year simulations,
- linked together through
- trade, aid, and capital flows.

1.2.3. Our approach – how it differs

To see how we built up our approach, let us look first at how others have viewed the field. Figure 2 shows the food and agriculture system as a black box. This approach is oversimplified – and even simplistic. The one-black-box approach neglects everything within the box, the national institutions and social elements, as well as the economic connections between the countries. There are many examples of this type of approach, in which the world's resources are summed to see how many people can be supported.

Figure 3 shows another approach, in which nations are the focus of attention. In this figure the large black box is the environment of the nations within it. Here nations are described in a very accurate and detailed way, but everything outside the countries' borders is neglected.

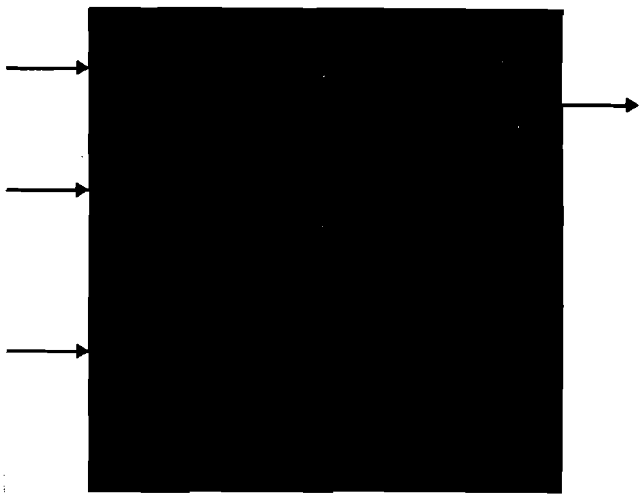


FIGURE 2 The global food and agriculture system as a black box.

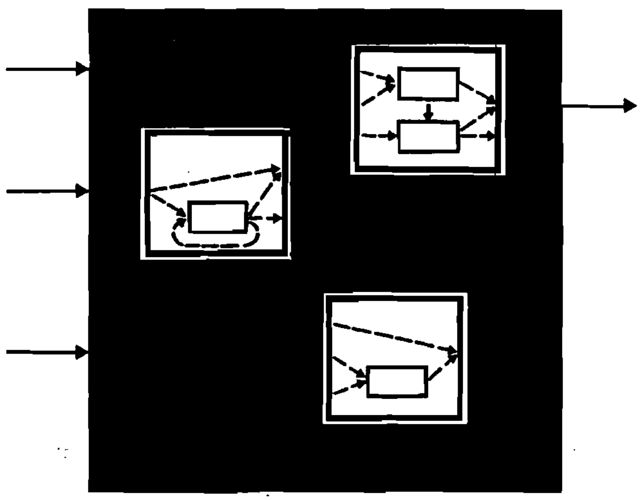


FIGURE 3 The global food and agriculture system as a set of unlinked national models.

Many researchers feel that this approach is not adequate and thus have tried to connect the national models by various linkages based on a variety of assumptions, as indicated in Fig. 4. There are two well-known experiments that take this approach.

- The LINK Project links existing national models while replacing and overruling their export functions with a heuristic algorithm.
- The United Nations approach assumes that the countries import everything they need for a given rate of growth and that these imports are covered by exports, the export shares being constant for the entire projected period.

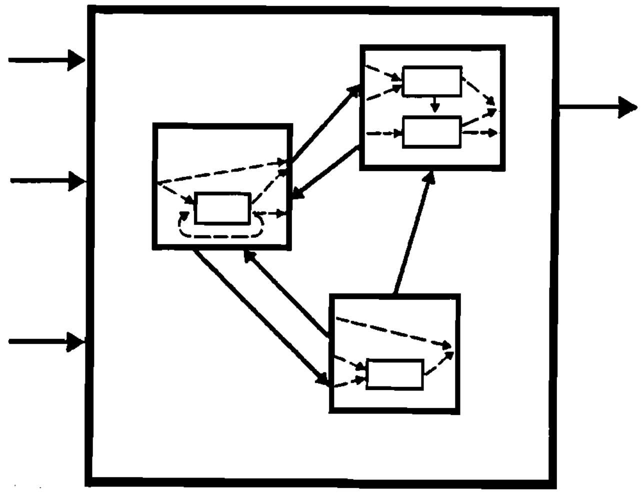


FIGURE 4 The global food and agriculture system as a set of national models with assumed international links.

Figure 5 shows yet another approach, the so-called trade models, in which the nations are regarded as black boxes. Here the modelers concentrate on the flows between the countries, without taking into consideration what is happening within the countries. Their predictions use various techniques of extrapolating from past flows.

The real internal (national) and external (international) relationships in food and agriculture are shown in Fig.6. IIASA's approach tries to reflect both these relationships. Each country has the same structure: a production module, an exchange module, and a government module. It is important for the government to be represented, because government policies influence both the production and exchange functions. Another important feature is that the food and agriculture sector is not separated from the rest of the economy. Since the rest of the economy plays an important interactive role, the national models are closed, with the government budgets and balances of trade fully represented. These national models are connected together through an international linkage system of trade based on general equilibrium theory.

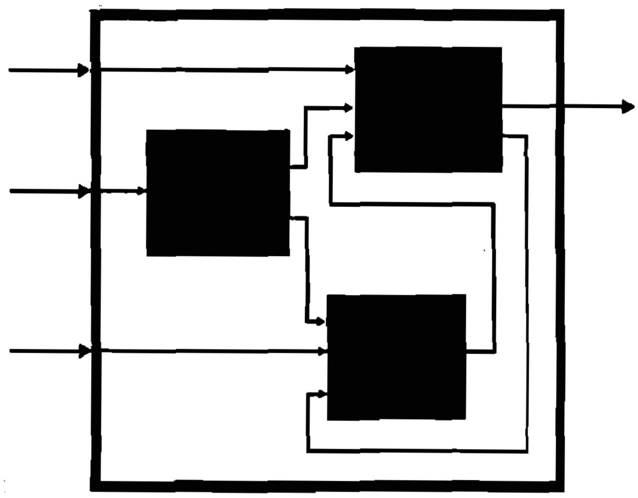


FIGURE 5 The global food and agriculture system as a set of flows between nations considered as black boxes (trade models).

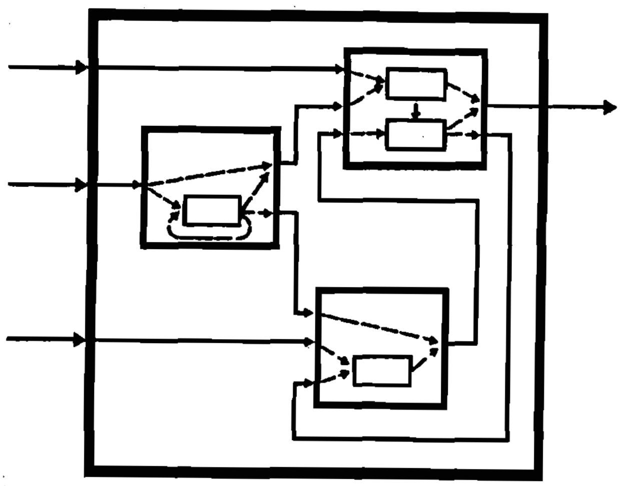


FIGURE 6 National and international relationships in food and agriculture.

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 for the FAP models differs from these early efforts in some important respects. 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 that 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.

The FAP analytical approach differs from other global models 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 attempt to introduce 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.

1.2.4. A typical national policy model of the FAP

The basic elements of the FAP model system are the national policy models. A national model has to reflect the specific problems of interest to that particular nation. Thus the national models differ in their structure and in their descriptions 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 Fig. 7.

Past prices and government policies affect production decisions. The domestic production in the n sectors of the economy – $y_1, y_2, \cdots, y_n$ – 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 $y_1^j, y_2^j, y_3^j, \cdots, y_n^j$. The income this share amounts to is determined by the price that these products command. For example, a farmer who has grown two tons of wheat and one ton of rice would have an income of twice the price of a ton of wheat plus 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 $j = 1, \cdots, J$ 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 Fig. 8.

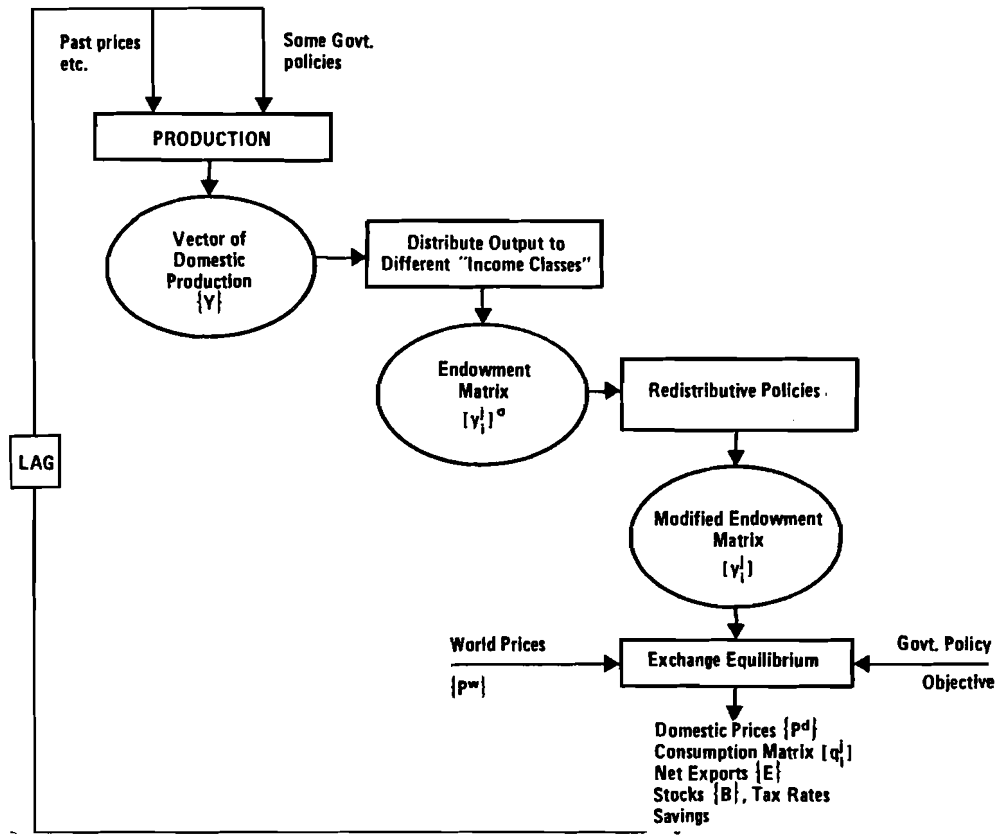
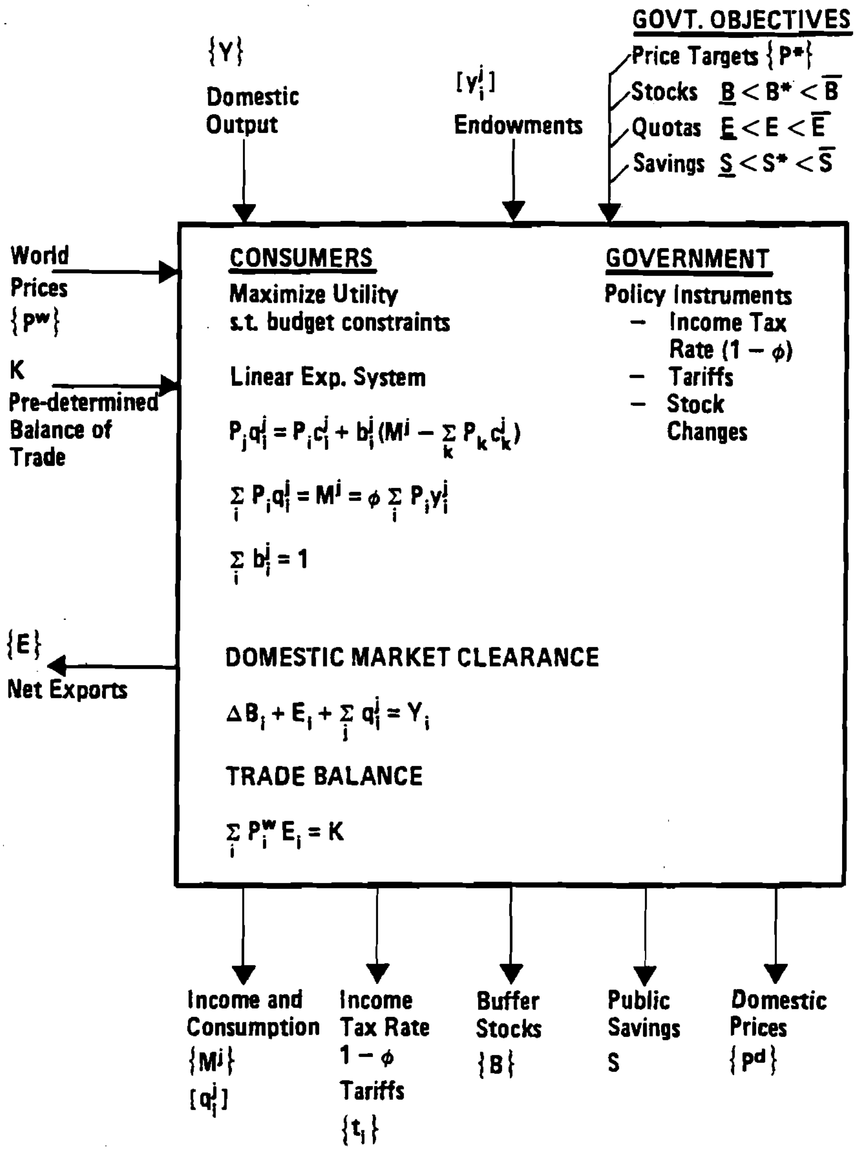


FIGURE 7 A typical national model.

1.2.5. The international linkage

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 shown schematically in Fig. 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.

This process yields both the domestic prices influenced by government policies and the international prices that are inputs to the next period, during which the governments and producers learn, not only from the price changes, but also from the changed supply-and-demand conditions. This learning process yields changed policies and product mixes for the next period.



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. tries 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 affects Domestic Availability and hence Prices

FIGURE 8 Computation of domestic equilibrium.

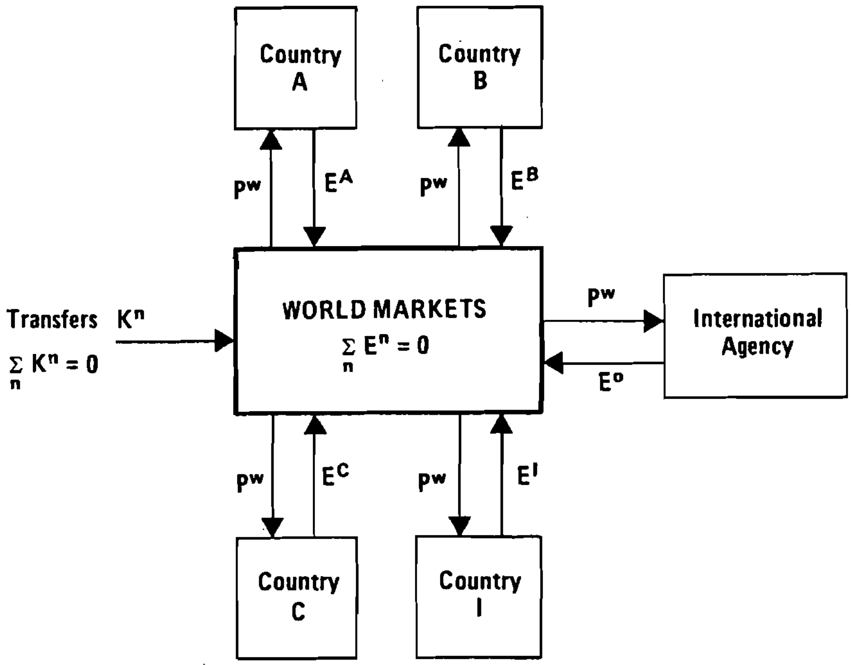


FIGURE 9 International linkage.

Since we go through these steps period by period, we have a dynamic simulation that we use in the short run (that is, for a 5- to 15-year period) to predict the consequences of various policies, not only for individual countries, but also for the entire system.

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.

1.2.6. Implementation – a network approach

To build detailed national agricultural policy models for the countries of the world is not feasible as one program of an institute of IIASA's size. 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 countries to a manageable number and still to cover the world agricultural system adequately for the analysis of the policy issues raised.

In choosing the countries for the simplified system, we wanted to represent different economic systems, different continents, and different problems. Our final choices include developed exporters, developed importers, centrally planned economies, and developing countries.

A selection of 23 countries, including some countries which have common agricultural policies treated as a group, covers nearly 80% of such important agriculture-related factors as the world's population, land (reflecting potential agricultural productivity), actual production, exports, and imports. Most of the remaining countries have individually a small impact on the international system and can be treated as one group – the rest of the world.

Table 3 gives the list of the countries selected, together with data on their importance in the world agricultural system.

TABLE 3 Percentages of world population, production of agricultural commodities, land base, and agricultural trade in 1976.[a]

Country	Population(%)	Production(%)[b]	Land base(%)	Imports[b] (%)	Exports[b] (%)
US	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
Finland	0.1	0.2	0.1	0.42	0.25
CMEA	9.0	16.7	17.5	12.72	5.74
Subtotal	25.0	46.9	34.8	72.53	62.01
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
Turkey	1.0	1.6	1.6	0.14	0.96
Mexico	1.5	1.5	1.3	0.35	0.82
Thailand	1.0	1.1	1.1	0.18	1.23
Brazil	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	53.8	35.4	47.7	7.08	17.29
TOTAL	78.8	82.3	82.5	79.61	79.30

[a]The figures are taken from Figure 4 in Ferenc Rabár (1979) Local Problems in a Global System. FAP Newsletter no. 3.
[b]Value in 1976 prices.

Even so, the development of 23 policy analysis models is still a task beyond the means of a single organization such as IIASA. Fortunately, IIASA provides a unique opportunity to focus the efforts of a number of groups and institutions around the world on a common set of problems. It is, however, more difficult for these groups and institutions to agree on 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 collaborating institutions is shown in Table 4.

TABLE 4 Institutions collaborating with the Food and Agriculture Program.

Centre for World Food Studies, Free University, Amsterdam	University of Nairobi, Kenya
Institute of Agricultural Economics, University of Göttingen, FRG	Swedish University of Agricultural Sciences, Uppsala
Michigan State University, East Lansing, US	Finnish Agricultural Economics Research Institute, Helsinki
US Department of Agriculture, Washington, DC	Institute of Agricultural Economy, Warsaw
Research Institute for Economic Planning, Budapest	Systems Research Institute, Warsaw
Indian Statistical Institute, New Delhi	Institute for Agricultural Economics, Austria
University of Tsukuba, Ibaraki, Japan	Agriculture Canada, Ottawa

The FAP group at IIASA commenced with the development of the methodology of linking the country models together as well as the methodology of the computation of domestic equilibrium under the influence of government policies. Simultaneously a few country case studies were begun. The interaction of these two activities enhanced 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 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 the 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 collaborating institutions with 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 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. They also serve as contact and dissemination points for national decision makers and serve to ensure that the work of FAP finds real-life applications.

The present status of the work on the detailed national models is summarized in Table 5.

TABLE 5 Status of detailed national agricultural policy models as of February 1981.

Complete and applied	Nearly complete	Well under way	Scheduled to start
Hungary	India	Egypt	Australia
CMEA	EC	US	New Zealand
	Brazil	Poland	Mexico
	Kenya	Austria	Nigeria
	Sweden	Japan	Pakistan
		Finland	Argentina
		Canada	
		China	
	Thailand[a]	Bangladesh[a]	Indonesia[a]

[a]Coordinated by Centre for World Food Studies, Amsterdam.

The establishment of this network of an international research community sharing a common approach to food and agricultural policy analysis is a significant achievement by the program, which could have been brought about only by an institute such as IIASA.

1.3. Task 2: Technological Transformations in Agriculture: Resource Limitations and Environmental Consequences

1.3.1. The food problem – future but not far

With a longer term perspective the food problem acquires further dimensions, and questions of the availability of resources to produce adequate food, the efficiency of techniques, and environmental consequences come to the fore. Certain trends can be perceived.

(a) Land will have to be cultivated much more intensively than at present. (See Appendix b, section 1, at the end of Part 1.)

(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 the limits of its potential, but water needs may approach the limits to exploitable supplies as well. (See Appendix b, section 2, at the end of Part 1.)

(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 higher yields required, 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.

(d) The increasing expense and uncertainty in energy supply will both increase the demand for land and make it harder to obtain higher yields through conventional techniques. (See Appendix b, section 3, at the end of Part 1.)

(e) Past estimates indicate a more than adequate ultimate food production potential, but these estimates have not fully taken account of environmental consequences and feedbacks in land productivity. (See Appendix b, section 4, at the end of Part 1.)

(f) A choice of agricultural production techniques offers alternatives not only of intensive as opposed to extensive cultivation but also of the intensification of various inputs such as fertilizer and water. Understanding the nature of technology is critical in formulating appropriate policies for promoting adoption and development of appropriate techniques. (See Appendix b, section 5, at the end of Part 1.)

We conclude from the foregoing that over the coming decades a technological transformation of agriculture will take place that will be constrained by resource limitations and whose environmental implications pose questions concerning the sustainability of adequate production to feed mankind.

1.3.2. Issues and approach

Since we anticipate over the coming decades a technological transformation of agriculture that will be constrained by resource limitations and that 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?

(c) What alternative transition paths are available to reach desirable levels of production?

(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 desirable properties from considerations of intergenerational 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 short-term strategies, Task 1, a general equilibrium approach, may be desirable. Such models exist in economics literature, and it has also been shown that solutions exist under certain restrictions which require, among other things, that consumer utility functions include public goods and that markets exist for externalities created by environmental consequences of production. Such an approach is not, however, empirically feasible.

Since we desire a long-term perspective here, a descriptive approach poses many difficulties. What we chose to do was 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 desirable. Since quantitative knowledge of environmental processes is not developed very far in the literature, we shall 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 6. 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 requirements, those agricultural activities are to be selected that would maximize net income from agriculture subject to certain constraints. Among these is included a sustainability constraint as well as environmental feedback relations.

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 shall 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 shall also obtain a global perspective.

Finally, the results of this task will be fed back into the short-run

TABLE 6 Technological transformation of agriculture: analytical framework – concept.

Given	$\{P^w_{it}\}$	Trade Prices
	$\{R_{it}\}$	Regional Requirements and
	Resource Base	
	$\{A^z_{fo}\}$	Area in zone z fertility class f
	$\{F^z_o\}$	Fixed capital stock, Water, Energy
Find	Activity Intensities $\{x_t\}$ which	
Maximize	net trade surplus,meet domestic requirement and are sustainable	
Maximize	$\sum_t \frac{1}{(1+\phi)^t} \sum_i \left[\left(P^w_{it} E_{it} + P^w_{it} R_{it} - P^d_{it} Y_{it}\right) - C_t(B_t, B_{t-1}, \ldots)\right]$	
s.t.	Inputs Bads	$\begin{Bmatrix} Y_t \\ B_t \end{Bmatrix} = [a_t]\{x_t\}$
Resource Limits		$\{x_t\} \leq \{A^z_{ft}\}$; $[b]\{Y_t\} \leq \{F^z_t\}$
Output Levels		$\{Q_t\} = [u]\{x_t\}$
Sustainability		$\{Q_t\} \geq \{Q_{t-1}\}$
Demand		$\{Q_t\} \geq \{R_t\} + \{E_t\}$
Feedback of Bads		$[a_t] = f[A^z_{f,t-1}]$
		$\{A^z_{ft}\} = g[A^z_{f,t-1}, B_t]$.
Multi-objective Large System Optimization		

strategy analysis models of Task 1, and modifications of medium-term policies from long-term considerations of sustainability would be obtained.

1.3.3. 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 processing 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 analytical framework and computer software.* These will be developed at IIASA.

(d) *Country case studies.* The countries or regions within countries for which work on case studies had already begun by February, 1981, were Hungary, Kenya, Czechoslovakia, the US, and the USSR. Additional case studies are being considered for Italy, Japan, 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.

1.4. Connections between tasks of the FAP

The two tasks are viewed as complementary. Both are essential to gain a real understanding of the food and agricultural systems. Figure 10 shows this connection.

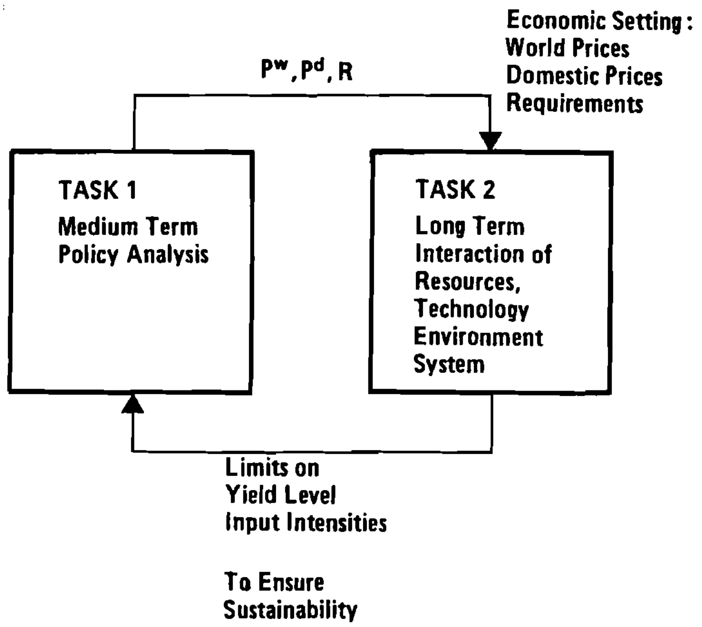


FIGURE 10 The connection between the tasks of the FAP.

The findings of Task 1 will provide a starting point for the scenarios of Task 2, providing a realistic basis for long-term 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.

References

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US Presidential Commission on World Hunger (1979) Global 2000 Report to the President. Washington, DC.

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Appendix a

a.1 Globally adequate food is available

That adequate food is available globally is shown in Table a1, where the per capita consumption of calories over the past few years is presented. Even given 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 supplies. The developing countries as a group have inadequate or barely adequate (considering the uncertainty of the norms) food supplies. Although the situation is improving, it is improving only slowly.

TABLE a1 Per capita daily supply of calories.

	Calorie Supply				Supply as Percentage of Requirement			
Region	1961–63	1964–66	1969–71	1972–74	1961–63	1964–66	1969–71	1972–74
	Kilocalories per Capita				Percentage			
Developed Market Economies	3.130	3.170	3.280	3.340	123	124	129	131
Eastern Europe and the USSR	3.240	3.270	3.420	3.460	126	127	133	135
Developing Market Economies	2.110	2.130	2.190	2.180	92	93	96	95
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 supplies. Unfortunately, for many of these countries the situation does not seem to be improving. This is shown in Fig. a1, in which the per capita calorie and protein consumptions for several countries between 1961 and 1976 are plotted.

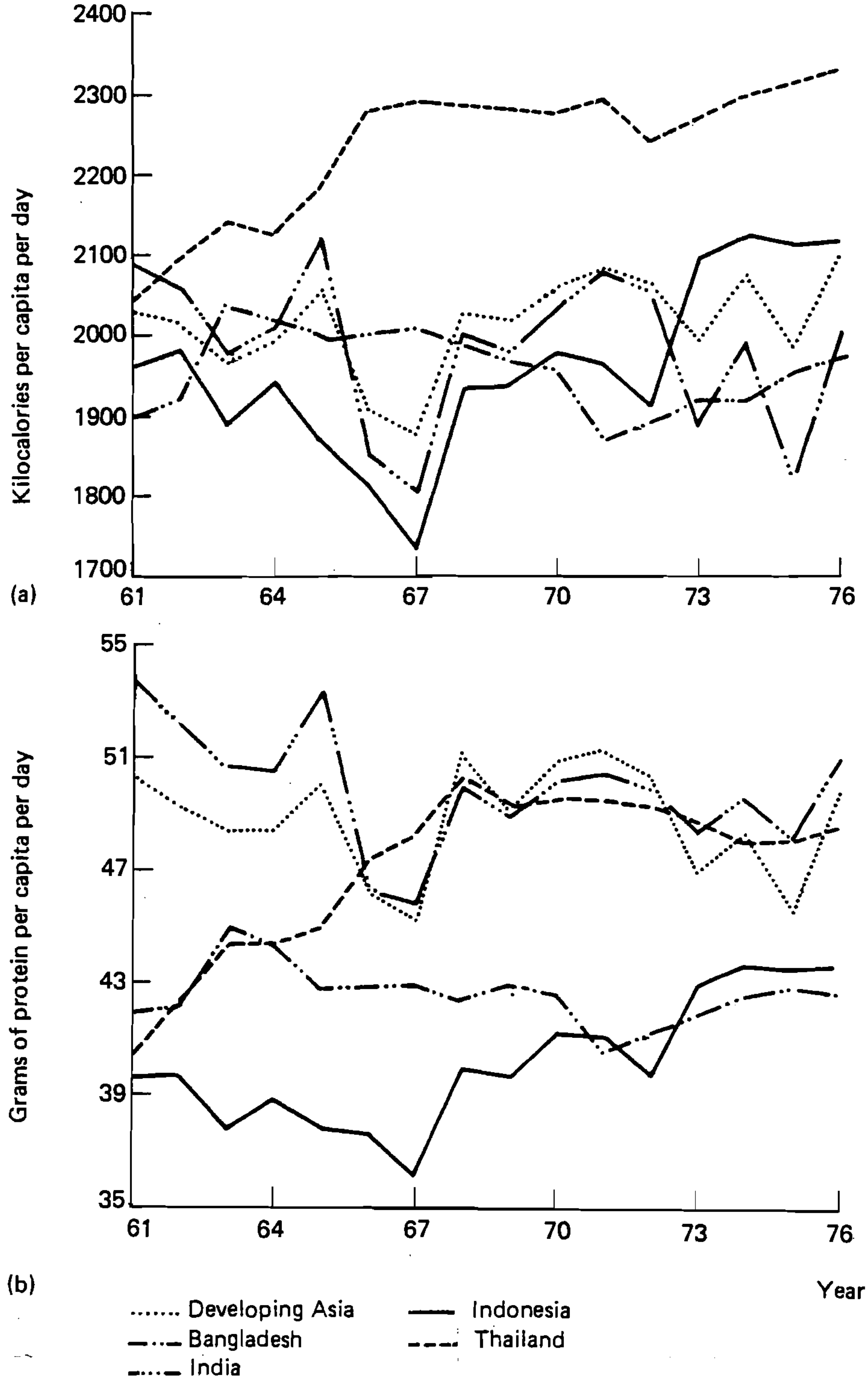


FIGURE a1 Per capita consumption of (a) calories and (b) proteins.

a.2 Importance of income distribution

The importance of considering income distribution in assessing the adequacy of food consumption within a country can be seen in Table a2, which shows the distribution of daily calorie consumption for India. It can be seen that in 1973–74, 38% of the population had a deficit in daily 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% of the population had a deficit of 1100 calories/person/day, and another 5% had a deficit of 680 calories/person/day.

TABLE a2 India, 1974 – Distribution of calorie consumption.

Income class	Percentage of total population	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	306
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 to June 1974.

A similar picture emerges from data for Kenya given in Table a3. For the country as a whole there is only a marginal calorie deficit, yet 40% of the rural population have a daily calorie deficit of 640 calories, and in urban areas 40% have a deficit of 340 calories.

a.3 Inadequate food – a significant and persistent problem

That the inadequate supply of food is an enduring problem is obvious from the number of people in absolute poverty. Although estimates vary, they all indicate a sizable problem. In 1980 for developing countries, excluding China and other centrally planned economies, the World Development Report (The World Bank, 1980, p. 33) estimated that approximately 780 million people did not have enough income to buy adequate food and minimum of clothing. The FAO estimates indicate that in 1972–74, 455 million people in these countries had a food intake below the critical limit of 1.2 times the basal metabolic rate (BMR).

* The calorie consumption figures of Table a2 indicate that there was no deficit in India for 1973–74, whereas FAO data on which Table a1 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 point made is valid: even more so if one were to rely on FAO data.

TABLE a3 Kenya, 1975 – distribution of calorie consumption.

Income class	Percentage of total population	Daily calorie consumption per person	Daily calorie deficit per person*
Rural			
1	39	1578	642
2	32	2077	143
3	19	2545	-
4	5	2867	-
5	2	2788	-
6	4	3036	-
Total	100	2069	151
Urban			
1	42	1787	343
2	25	2117	13
3	33	2453	-
Total	100	2086	44

*Moderately active rural requirement 2200 calories per day.
Urban light activity requirement 2130 calories per day.
Source: M. M. Shah, Calorie Demand Projections Incorporating Urbanization and Income Distribution. FAP, IIASA, 1978.

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 proportion of the world's poor. The data in Table a4 show that there has been no significant trend in the percentage of the rural population in poverty over the period 1959–1974.

a.4 Stepping up food production in developing countries – difficulties, needs, and problems

Increased 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 a5. 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 aggravate the balance of payments. Moreover, expansion of such exports may not be easy to achieve without a change in the international economic order.

TABLE a4 Percentage of rural population in poverty in India (by states).

	59–60	61–62	64–65	66–67	68–69	73–74
Andhra Pradesh	49	47	42	48	47	40
Assam	31	30	24	47	47	39
Bihar	56	50	54	74	59	58
Gujarat	42	40	50	54	43	36
Karnataka	49	35	55	60	59	47
Kerala	62	50	61	67	65	49
Madhya Pradesh	46	40	42	58	56	52
Maharashtra	55	44	59	63	55	50
Orissa	63	49	62	64	71	58
Punjab and Haryana	24	22	27	30	24	23
Rajasthan	n.a.	33	32	37	41	30
Tamil Nadu	64	51	57	63	61	48
Uttar Pradesh	37	35	54	55	46	47
West Bengal	61	58	64	64	75	66
INDIA (Weighted averages)	49	42	50	57	53	48

Source: Ahluwalia, M.S. (1978) Rural Poverty and Agricultural Performance in India, Journal of Development Studies, Vol. 14, April 1978, pp.298–323.

TABLE a5 FAO's AT 2000 projections for 90 developing countries based on trend rates.

	1980	2000
Aggregate calorie self-sufficiency ratio	0.92	0.80
Cereal imports of deficit countries	47 m. tons	180 m. tons
Net meat deficit	–0.4*m. tons	14 m. tons
Agri. commodity net trade balance (1975 billion $)	6 billion $	–36 billion $
Average calorie consumption per person per day	2278 calories	2489 calories
Population undernourished	415*m. (22%)	390 m. (11%)

*1974–75

Source: Agriculture: Toward 2000. FAO, c79-24, November 1979.

To step up agricultural growth rates in developing countries beyond the trend rates, increased availability of inputs and capital resources is required. Table a6 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 a more equitable distribution of food are also largely matters of national policies.

The 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 in the FAO study.

TABLE a6 Production and key inputs for 90 developing countries. (Index, 1975 = 100 unless otherwise stated)

			Annual growth rates	
	1980	2000	1963–1975	1980–2000
Gross value of agri. production	115	244	2.6	3.0
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, November 1979.

a.5 Hunger is a complex phenomenon: the importance of national policies

Increased production is not in itself adequate to ensure that all will have enough to eat. Appropriate government policies are necessary too. This can be seen from the analysis of the circumstances associated with four famines shown in Table a7. 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) of the four famines, the economy of Bengal was booming.

a.6 Global interdependence in agriculture: importance of trade

The importance of traded calories in human consumption is shown in Figs. a2 and a3. The populations of the countries from those 56 selected are grouped together based on their net imports of calories and proteins as percentages of human consumption of calories and proteins and are plotted as percentages of the total population of the 56 countries. It is seen that 15% of the population depends on net imports of calories for more than 30% of its consumption. Figure a3 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% of its final human consumption as computed in terms of both calories and proteins.

Moreover, agricultural imports form a sizable part of the trade of many countries. This can be seen from Fig. a4, which gives the distribution of population by share of agricultural imports in the total

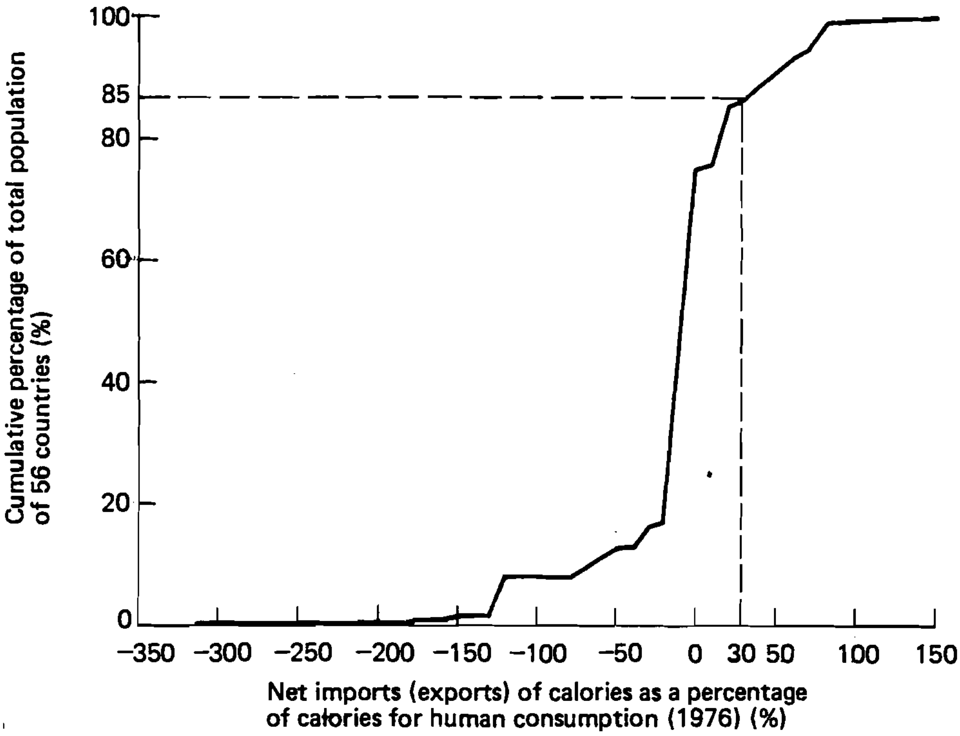


FIGURE a2 Imports of calories as a percentage of total calories for human consumption.

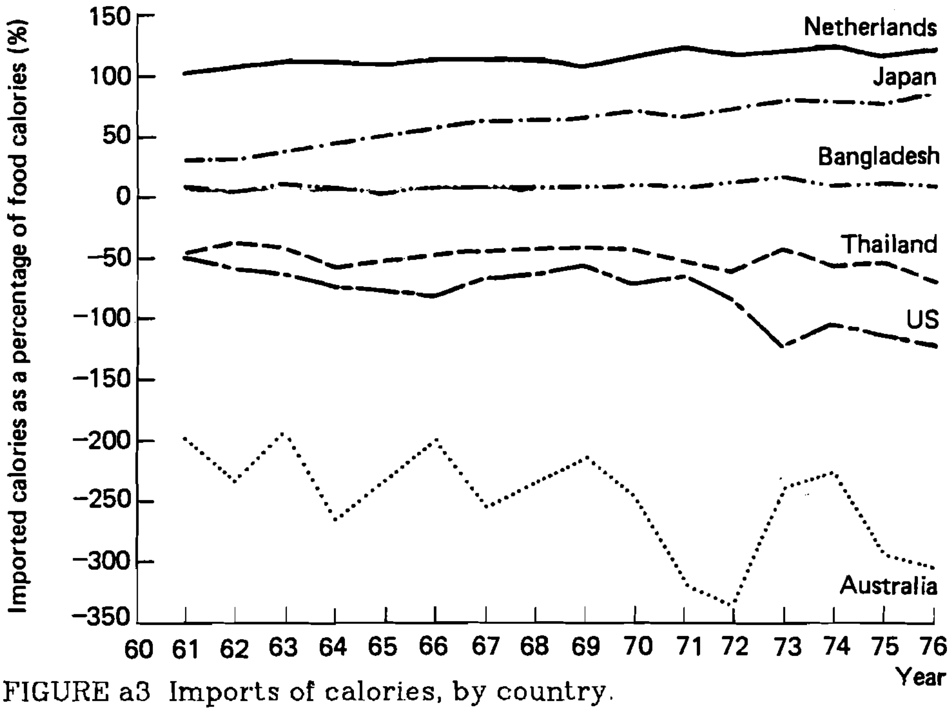


FIGURE a3 Imports of calories, by country.

TABLE a7 Comparative analysis of four famines.

Famine	Was there a collapse in food availability?	Occupation group which contained the largest number of famine victims	What was the general economic climate?
Bengal famine 1943	No	Rural labor	Boom
Ethiopian famine (Wollo) 1973	No	Farmer	Slump
Ethiopian famine (Harerghe) 1974	Yes	Pastoralist	Slump
Bangladesh famine 1974	No	Rural labor	Mixed

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

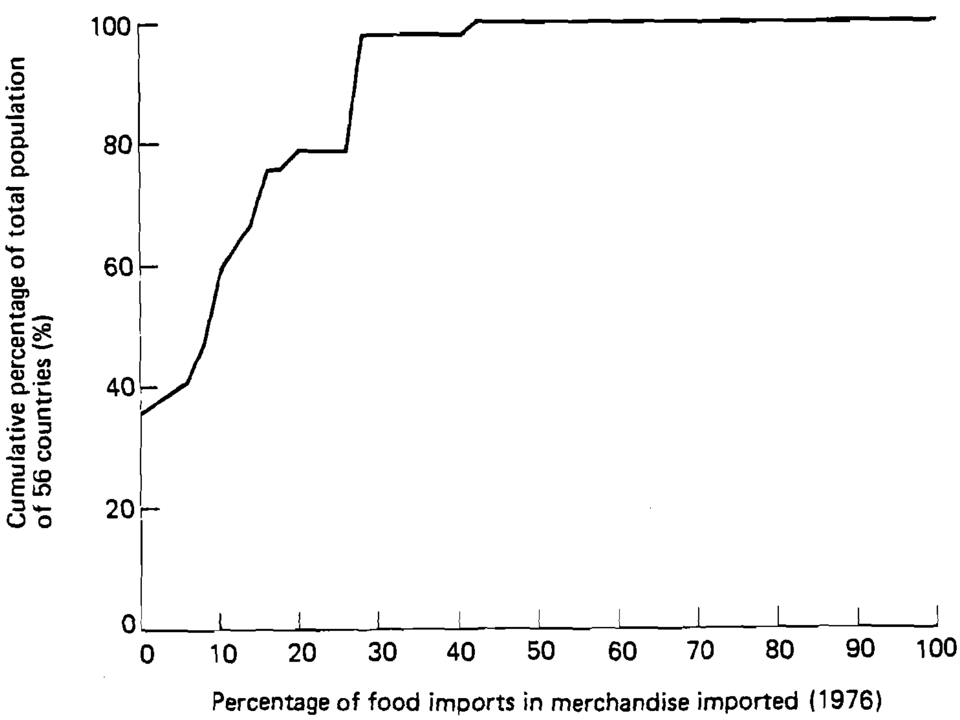


FIGURE a4 The importance of agricultural imports in trade.

merchandise imports of the country. In value terms 40% of the population of the world lives in countries for which this share was more than 10%, whereas for 20% of the population they exceeded 20%.

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 Figs. a5 and a6. Five exporting countries account for more than 60% of the total exports of calories and 70% of exports of cereals and proteins.

a.7 Endemic variability and uncertainty in agricultural production

Yields of rice, coarse grains, and wheat, given in Fig. a7 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 fluctuations in agricultural production.

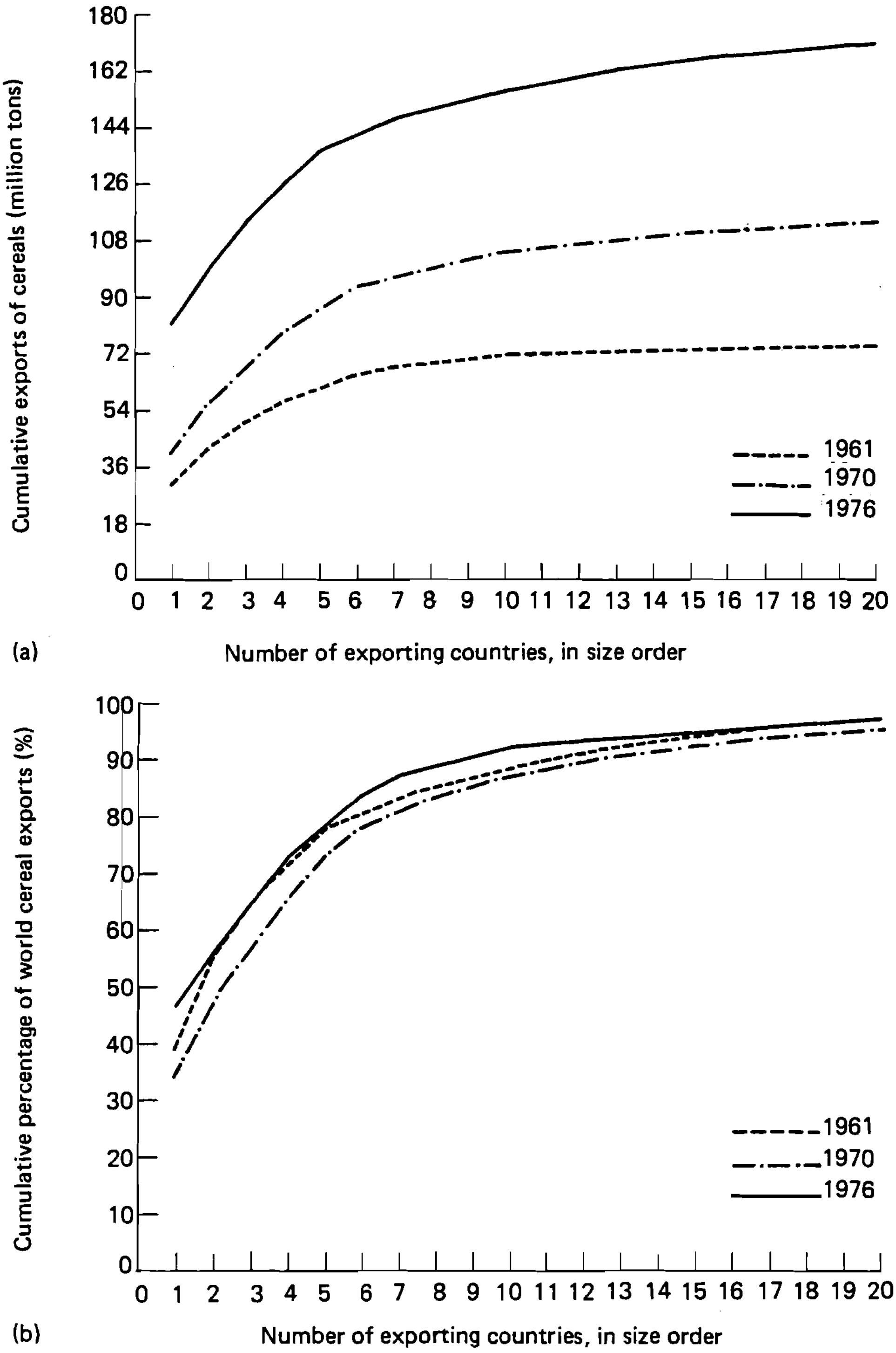


FIGURE a5 (a) Cumulative exports of cereals and (b) cumulative percentage of world cereal exports, by country.

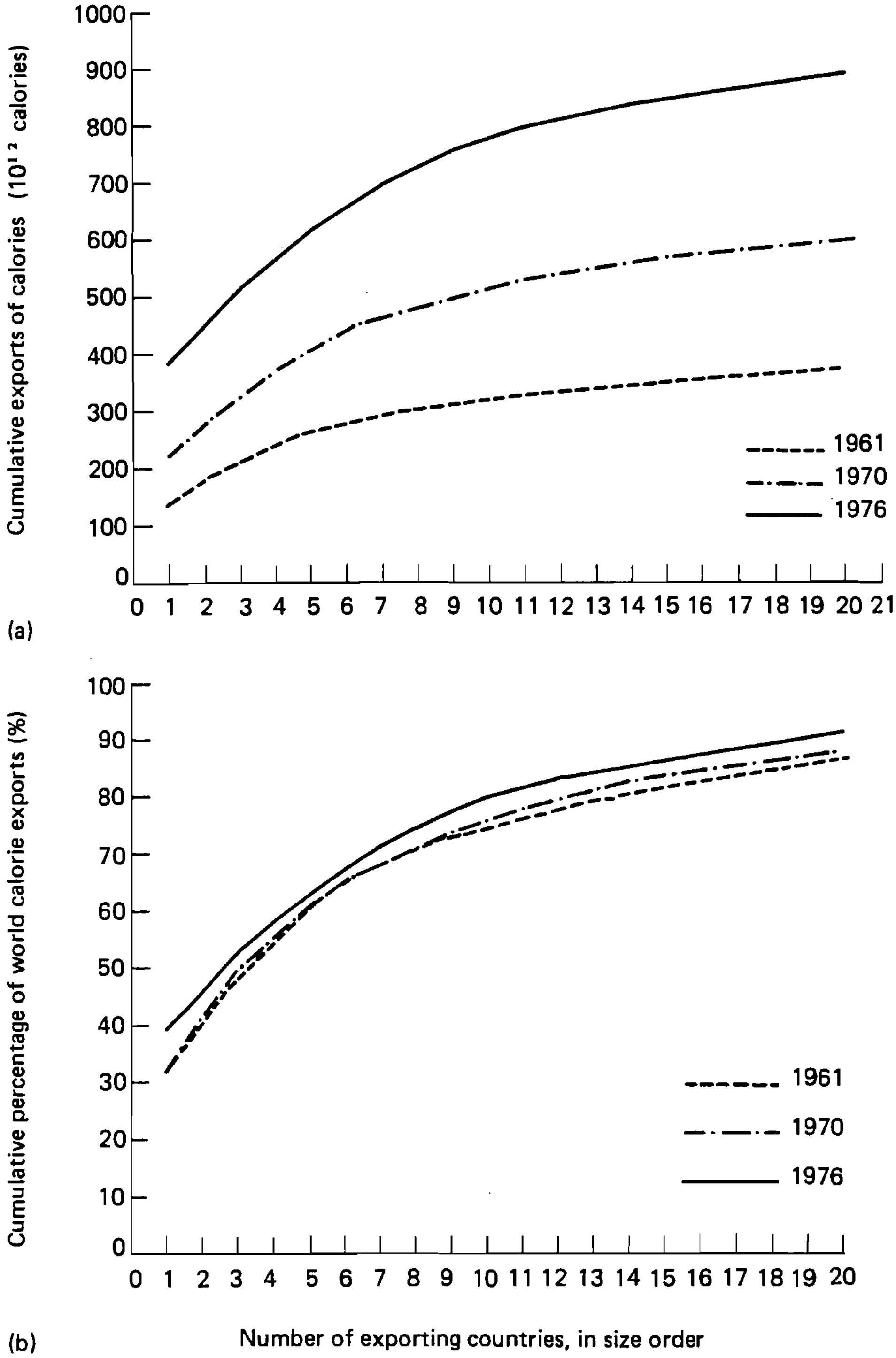
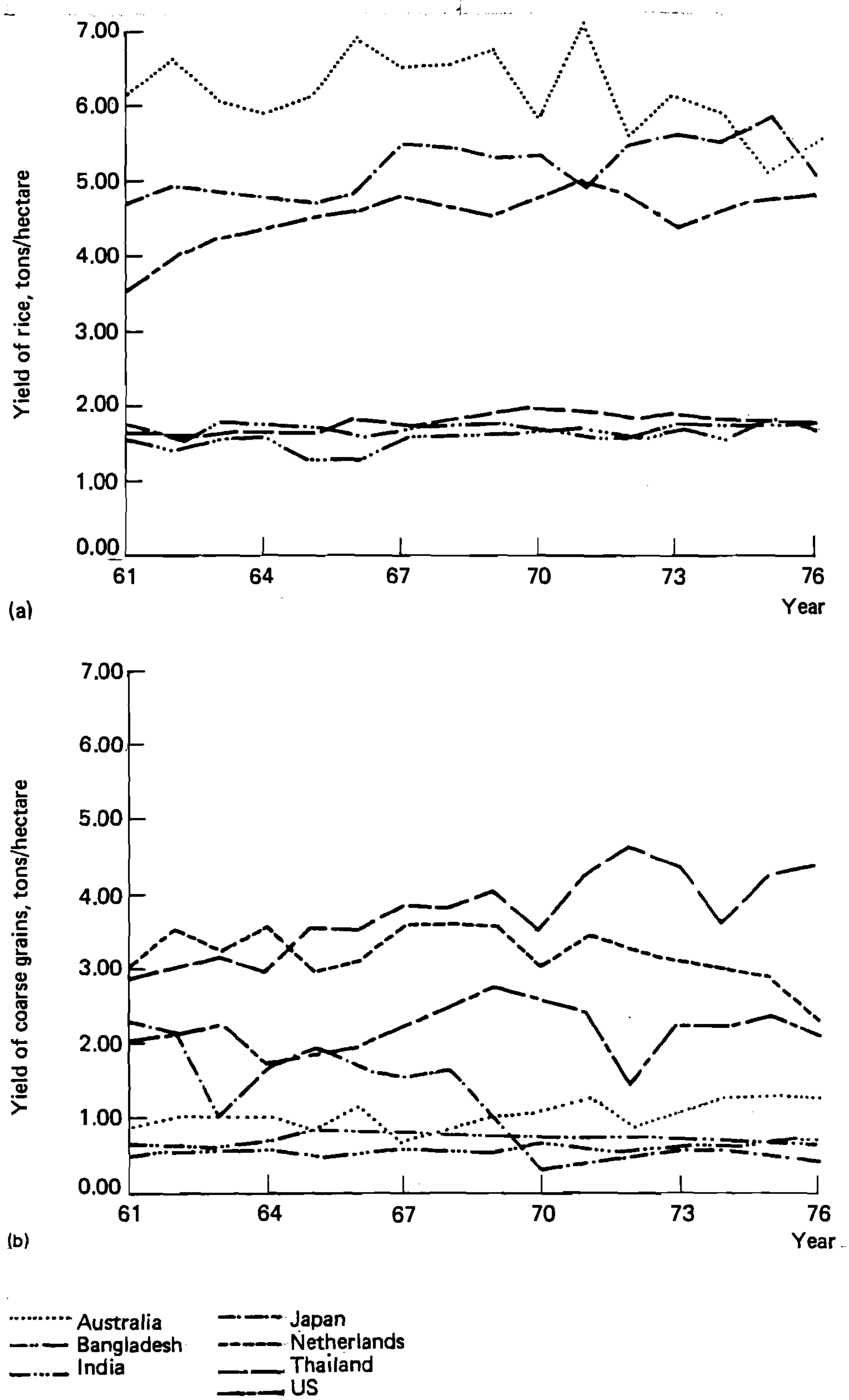


FIGURE a6 (a) Cumulative exports of calories and (b) cumulative percentage of world calorie exports, by country.



7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Yield of rice, tons/hectare
61
64
67
70
73
76
Year
(a)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Yield of coarse grains, tons/hectare
61
64
67
70
73
76
Year
(b)
Australia
Bangladesh
India
Japan
Netherlands
Thailand
US

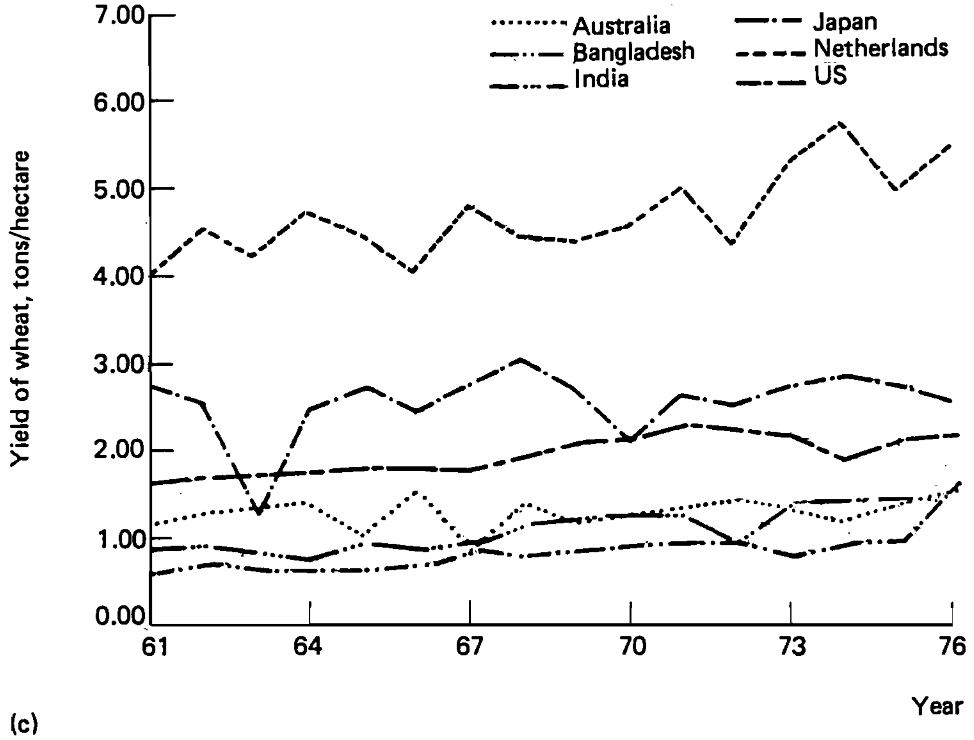


FIGURE a7 Yields of (a) rice, (b) coarse grains, and (c) wheat, 1961–1976.

Appendix b

b.1 Increasing pressure on land

The pressure on land will arise from 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 b1 shows the effect of increasing population as projected by The Global 2000 Report to the President (1979).

TABLE b1 Arable area per capita, actual and projected (alternative I).

	1951–55	1971–75	1985	2000
Industrialized countries	0.61	0.55	0.50	0.46
Western Europe	0.33	0.26	0.24	0.22
Centrally planned countries	0.45	0.35	0.30	0.26
China	0.19	0.16	0.13	0.11
Developing countries	0.45	0.35	0.27	0.19
World	0.48	0.39	0.32	0.25

Note: Double crop area counted only once, includes temporary crops, current fallows, pastures and kitchen gardens.
Source: The Global 2000 Report to the President, Vol. 2, Table 6-13, p. 99.

The normative scenario of the FAO's Agriculture: Toward 2000 shows a similar picture. By the year 2000 more than 60% 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% are projected between 1980 and 2000. All of these will call for the intensification of the cultivation of land.

b.2 Water and fertilizer needs

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 effect would be exacerbated by greater industrial use – such as for power generation – as well as higher demand due to increased urbanization and the improved sanitation standards of the growing populations of the developing countries.

The FAO normative scenario projections for irrigation needs are shown in Table b2. The required increases in the use of fertilizers are also indicated.

TABLE b2 Projected irrigation and fertilizer needs of developing countries: FAO 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, November 1979.

TABLE b3 Estimates of world water use pattern.

	Percentage of total water use	
	1967	2000
Agriculture	73	53
Domestic	5	6
Industry and Mining	22	41

Source: The Global 2000 Report to the President, Table 9-5.

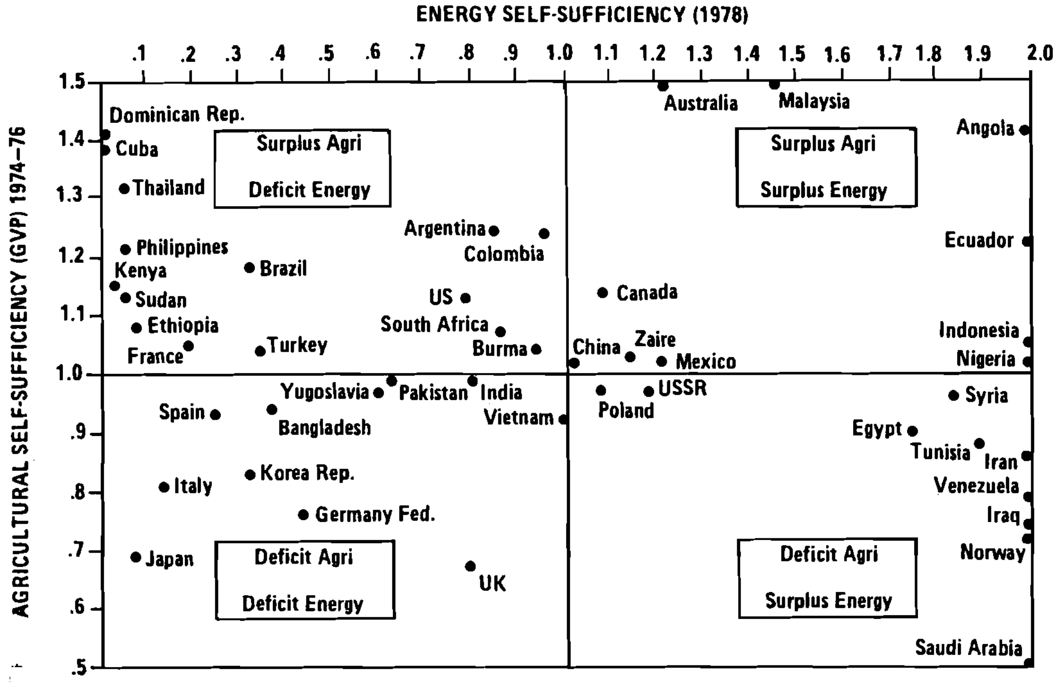
Table b3 shows the growing importance of water demand for industrial and urban uses.

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 less than 20 years ahead. A perspective beyond 2000 would call for even greater intensification.

b.3 Energy – the critical factor

Expensive energy not only makes fertilizer and lift irrigation expensive but also tempts energy-deficient countries that have food surpluses to divert their land to energy plantations. Figure b1 shows a plot of countries according to their energy and agricultural self-sufficiency. The countries in the left top group are those likely to turn to energy plantations. Since these include the major food exporters of today (US, 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 obtain even higher yields from their land.



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

FIGURE b1 Energy and agricultural self-sufficiency.

b.4 Estimates of global population-supporting capacity – can it be sustained?

Table b4 summarizes some of the estimates made of the world's ultimate production capacity. Although the estimates show a wide range, the lowest indicates adequate potential to feed more than 8 billion people, and the highest is as much 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 b5 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 would rise to 17.

TABLE b4 The world's food resources converted to estimates of the number of people that can be fed by them.

Study author	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: Clark, 1967; Klatzman, 1975; Linnemann et al., 1977; Revelle, 1974; University of California, 1974.

TABLE b5 Number of African critical/danger countries at year 2000, i.e. having a projected population greater than their assessed potential population-supporting capacity.

	Present crop mix	Improved[a] crop mix
Low level of inputs		
No conservation measures	34	30
With conservation measures	27	23
Intermediate level of inputs		
No conservation measures	17	12
With conservation measures	13	10
High level of inputs		
No conservation measures	12	11
With conservation measures	8	5[b]

[a]A crop mix that maximizes calorie production subject to protein constraint.
[b]Countries such as Djibouti, Cape Verde, Lesotho, Rwanda, and Western Sahara, which have very little arable land.
Source: FAO/UNFPA, 1979.

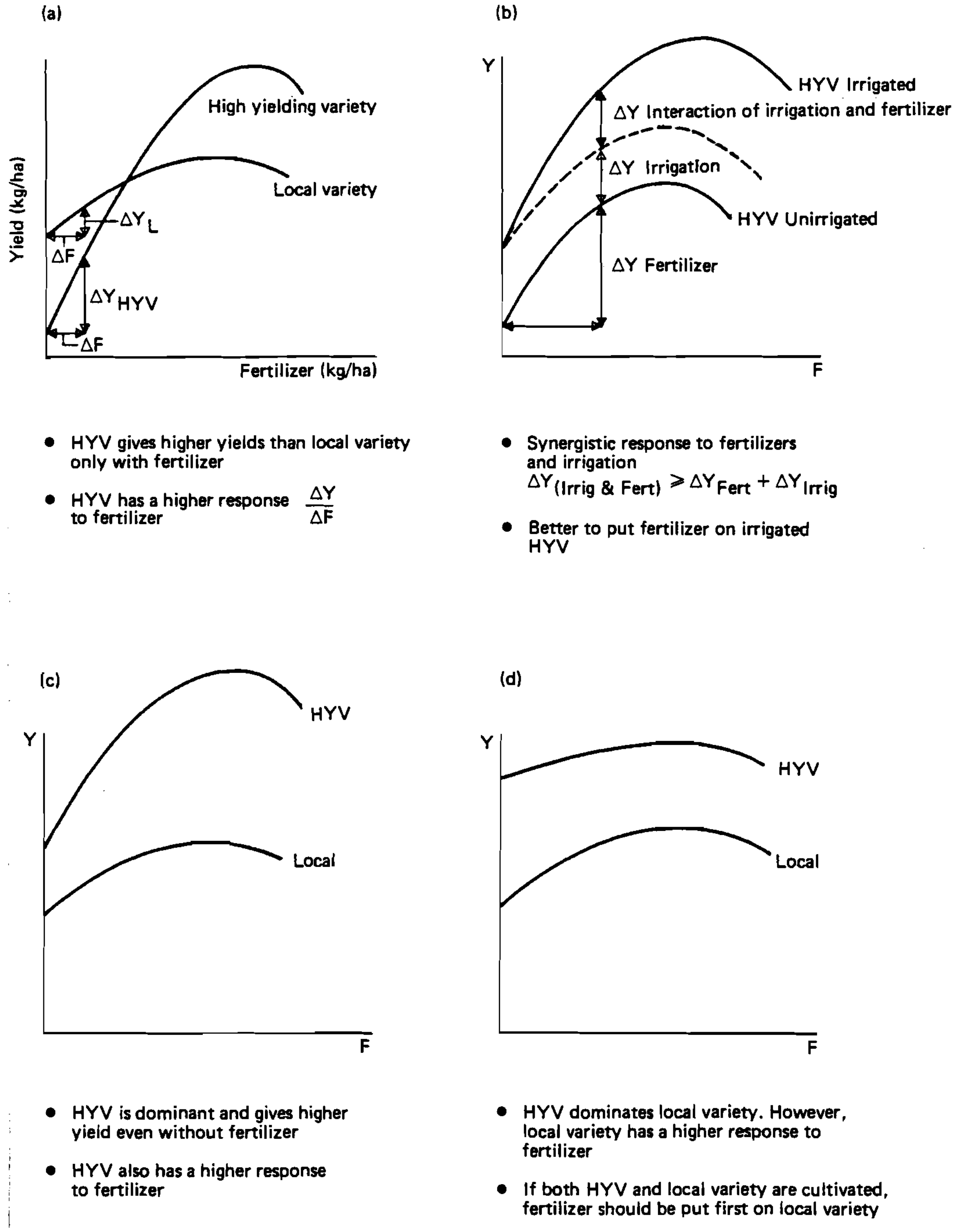
b.5 Policy implications of nature of technology

The policy implications of the nature of technology can be illustrated by an examination of the new high yielding varieties. The conventional wisdom regarding the nature of the high yielding varieties (HYV) which have ushered in the "green revolution" includes the following beliefs:

(1) The HYVs give higher response to fertilizers than the "local" varieties;

(2) The HYVs need fertilizer and irrigation for realizing their higher responses;

(3) The HYVs respond synergistically to a package of inputs and practices, the most important among the inputs being the three fertilizers – nitrogen, phosphorus and potash – and irrigation;



Source: Parikh, 1980.

FIGURE b2 Policy implications of nature of yield responses.

The policy implications of these beliefs are obvious:

(1) It is more efficient to allocate fertilizer to HYVs than to "local" varieties;

(2) HYVs should be adopted only when the availability of water and fertilizers is assured;

(3) Since inputs act synergistically, it is more efficient to concentrate the developmental efforts in selected areas for promoting intensive agriculture.

However, based on the extensive analysis of the data on yield responses to fertilizer that was carried out by Parikh et al. (1974), Parikh (1980) has questioned the conventional wisdom regarding the nature of the HYV technology, at least at the low level of inputs used by Indian farmers, and consequently questions the policy implications described here. The implications of some of the possible types of yield responses are summarized in Fig. b2, where (a) and (b) correspond to the conventional view described. In Fig. b2(b) the broken line has been obtained by shifting vertically, by an amount equal to the increase in base yield due to irrigation, the response line for unirrigated HYV. The broken line thus represents what would be the response function for irrigated HYV if there were no interaction between irrigation and fertilizer. From his analysis, however, Parikh has argued that the yield response functions are certainly such that the HYVs are dominant, as shown in Figs. b2(c) and b2(d); for some cases the slope of the response functions may be more like case b2(d) than b2(c).

References to Appendix b

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PART 2. LINKAGE AND SIMPLIFIED SYSTEMS

2.1. THE INTERNATIONAL LINKAGE OF OPEN EXCHANGE ECONOMIES – A SUMMARY VIEW

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2.1.1. Policy Analysis in Food and Agriculture – Principles and Framework

The purpose of the FAP is to study the effect on the domestic food situation in given countries of alternative policy measures as taken by their own governments, by the governments of other countries, and by international organizations which operate under specified international agreements.

In specifying the operation of the food system we distinguish between the main staple foods, nonfood agricultural crops, and residual nonagricultural sectors, thus covering the whole economy. This full coverage is required in order to describe not only food supply but also income formation and the income of dependent food demand. Food supply and demand is treated by income group, and this may range in definition from, say, landless farmers in a specified region to the whole nonagricultural rural sector of the country. Income groups are one type of basic actor in the system, the other type being the national government. The main principle selected in modeling the food system is to distinguish these basic actors in order to try to describe their behavior accurately and to integrate this behavior through the imposition of accounting rules. It is the imposition of these accounting rules on the behavior of the basic actors that generates the behavior of the system as a whole. This approach is commonly called a "general equilibrium" approach in the economics literature. It is followed not only at the national level, where the income groups and the national government are the basic actors, but also at the international level where countries interact with each other as well as with international organizations. Figure 1 illustrates this.

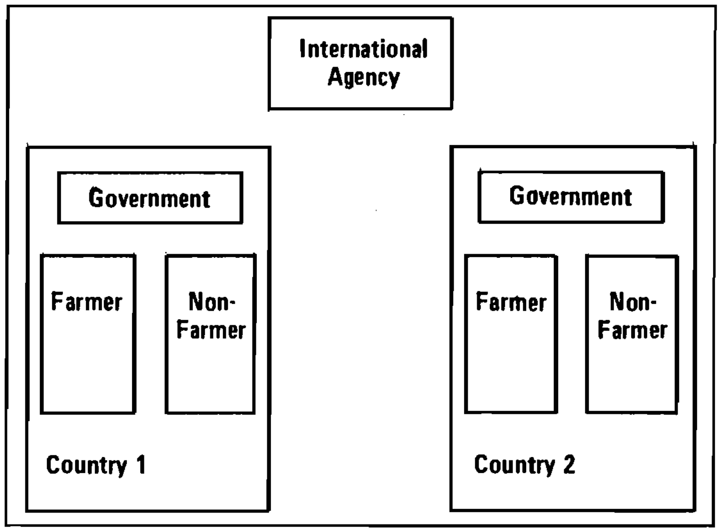

FIGURE 1 Actors in the international model.

2.1.2. Operation and Main Linkage Requirements of a Country Model

Each country model consists of income groups such as farmers and non-farmers and of a national government. Each income group makes production decisions on the basis of current prices and brings the products to market in the *next year*; thus production plans cannot adjust within the year. Given this ownership of marketable commodities, the income groups engage in an exchange process during which consumption, savings, and investment take place (see Fig. 2). As a consequence prices are formed and international trade flows are generated. The government also affects the exchange process through its policies, but the nation as a whole is taken to be subject to international prices, and (in the current version of the model) national trade deficits (i.e., the value at international prices of the net imports) are given as well. This is shown in Table 1. The government behavior will be further explained in the following.

The system operates as follows: for any given year of simulation and every country the exchange is solved at given values of international prices and trade deficits. The international exchange is solved by iteratively changing prices and trade deficits until the aggregate behavior of the nation satisfies the accounting rules which were imposed. On the basis of this solution the supply plans for the next year of simulation are formulated in each country, etc. These are now the basic requirements for a country model to be linked into this system.

First, of course, there are accounting requirements. In order to be able to check whether accounting relations are satisfied at the international level, all countries must generate compatible information at given time intervals; they must therefore have a common time increment (one year) and follow a common commodity classification.

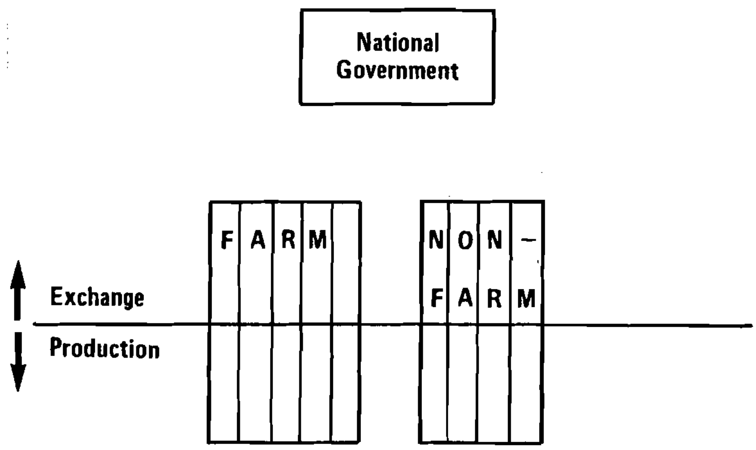

FIGURE 2 The national model.

Second, we must be assured of the existence of a solution at the international level. This can be ensured under several sets of conditions, but the one selected here is that the net imports of each nation should be a continuous function of international prices and of a given trade deficit (in the most recent version of the system, trade deficits are not given but can adjust within bounds). The trade deficits should add up to zero at world level. Furthermore, the condition needs to be imposed that the absolute level of international prices should not influence net imports. Obviously these are minimum requirements, since they only guarantee that the national models can be linked from a computational point of view. They do not ensure any theoretical consistency between the national and the international models. In order to ensure this theoretical consistency, we have to go a step beyond the design of a methodology for linking national models to develop a methodology for linking income groups and government within a national model. To this end, government policies and the adjustment mechanisms of the national economy have to be specified.

2.1.3. Government Policies

The main policy variables that can be handled by the model in its present version are listed in Table 2. How a policy is actually represented will be outlined in what follows. Here, it suffices to say that government is thought to pursue market policies which directly influence price, stock and trade in each commodity. A price policy can be pursued through a tariff or indirect taxes, a buffer stock policy through the operation of a public buffer stock agency which announces that it will buy and sell unlimited quantities at quoted prices. A trade policy should primarily be thought of as the imposition of quantitative constraints (quotas) on net imports. These constraints may in some cases reflect the nontradability of a commodity rather than an explicit government policy. Market policies are commodity specific but have an impact on the tariff receipts,

TABLE 1 Exchange: the general equilibrium model.

SUBMODEL (Actor)	INPUT	OUTPUT	TYPE OF RELATION
(A) INCOME GROUP			
(Demand: Farm, Non-Farm)	– Ownership of goods – Producer price – Income – Income tax – Retail price	– Income – Consumption/saving/ investment	– Accounting – Econometric
(B) GOVERNMENT			
(Market Policy, Tax, Public Demand)	– International prices – Trade deficit – Net demand by income group	– Income + indirect tax – Target prices – Quota on trade – Buffer stock – Public demand	– Hierarchical
(C) DOMESTIC MARKET			
(Equilibrium)	– Net demand (government + income groups) – Target prices, quota, indirect tax	– Retail/producer prices – Net import	– Accounting
(D) INTERNATIONAL MARKET			
(Equilibrium)	– Net import, all countries – Rules of agreement	– International prices – Trade deficits by country	– Accounting

cost of stockholding, tax receipts – in short, on the financial side of the economy, wfere the government also has a choice of adjusting taxes, public expenditure categories (defense, education, public works, etc.), or the balance of trade deficit. At the international level market policies can be effected, and have to be financed, by the participating countries.

2.1.4. Policy Adjustment and the Imposition of Accounting Identities

It was mentioned in section 2.1.1 that the general equilibrium approach is characterized by the imposition of accounting rules (i.e. identities) on the behavior of the basic actors. We have just listed the main government policies and shall now discuss how these policies can be made consistent with each other and with the accounting rules. We consider two types of accounting rules: first, the market clearing identities which state that supply should equal demand; and second, the budget equations which state that total expenditure should equal total earnings.

When the behavior of all the actors has been specified without taking these identities into consideration, the satisfaction of these identities can only be ensured if some variables adjust. Alternatively, the

TABLE 2 Policy variables in the model.

(A) National Market Policies (Incl. Money)
- **Price**
- **Buffer Stock**
- **Trade**

(B) Public Finance
- **Balance of Payments**
- **Public Demand**
- **Direct Tax**

(C) International Market Policies + Finance
- **Agreements on**
  - **Price**
  - **Buffer Stock**
  - **Trade**
  - **Financing of Agreement**

imposition of these identities can thus also be looked upon as a means of describing the development of the adjustment variable.

Which variable should be taken as an adjustment variable? Clearly, if the government finds the value of a variable very important, it will not accept any deviation from a target, and therefore will not allow that variable to adjust in response to financial or market pressures. Thus, the government plays an important role in determining the conditions under which variables adjust. The specification of the adjustment conditions should not be confused with the more common distinction between policy instruments and policy targets or, more generally, between endogenous and exogenous variables. It does not seem realistic to specify a priori what the targets and the instruments are to be, since the government is likely to be interested in the outcome of several interdependent variables for each of which it could specify target values. It is also unrealistic to assume that government merely steers the economy toward single-valued target levels, and we would rather expect that government wishes to keep variables within specified sets (i.e. inequality constraints) and that it has a certain ordering of preferences over these sets.

To explain how this approach is implemented, we take the example of a set of policies for a single commodity – for example, wheat. We specify targets and bounds for the price as well as the net exports, as illustrated in Fig. 3. The government would like the price to have value $\hat{P}$ and exports to have value $\hat{E}$, but it wants at any rate price and export combinations to be within the quadrilled region. However, it further restricts the outcome to the heavy line in Fig. 4 (X for price, Y for net exports), where, for example in (b), the price should be on target as long as net export is within bounds, and should not be above target when the net export is at its upper bound and not below target when the net export is at its lower bound.

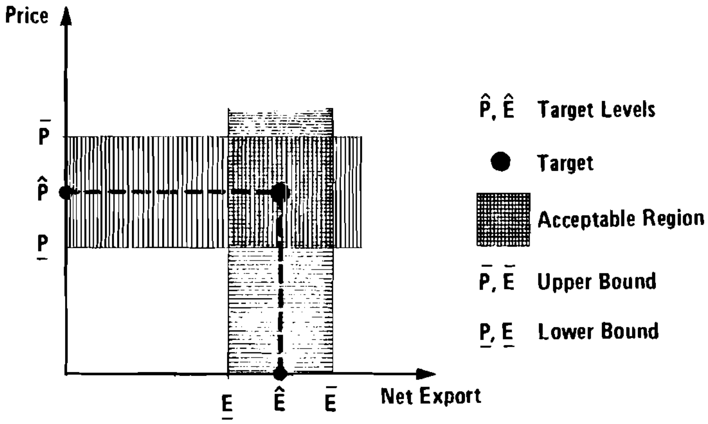

FIGURE 3 Target and bounds on price and trade policy.

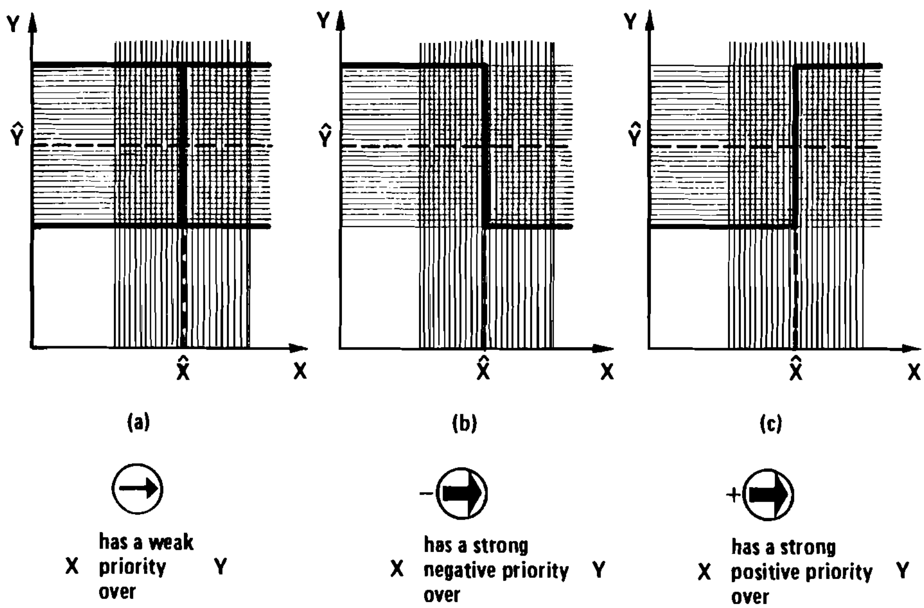

FIGURE 4 Policy adjustment rules for the government.

Figure 4, (a), (b) and (c), describes in a general way alternative adjustment rules. Again, the heavy line describes the set of outcomes which are assumed to be acceptable to the government.

Now let us think of a buffer stock scheme in which government would buy at price $\underline{P}$ and sell at price $\overline{P}$. Clearly, we must now leave the two-dimensional world. Figure 5 shows the priority of price over net exports, while Fig. 6 illustrates that stock only deviates from target when price is at bound. We must now combine the two plots into one consistent policy as illustrated in Fig. 7. First, all variables may be at their target as indicated with a black dot. Net export adjusts first. Second, price is allowed to adjust and then stock. Finally, when stock is at a bound, price has to adjust again. Again the heavy black line indicates the region acceptable to the government. It is not known a priori in which region the solution will lie, and the existence of a solution can only be shown if the policy adjustment rules are adequately specified.

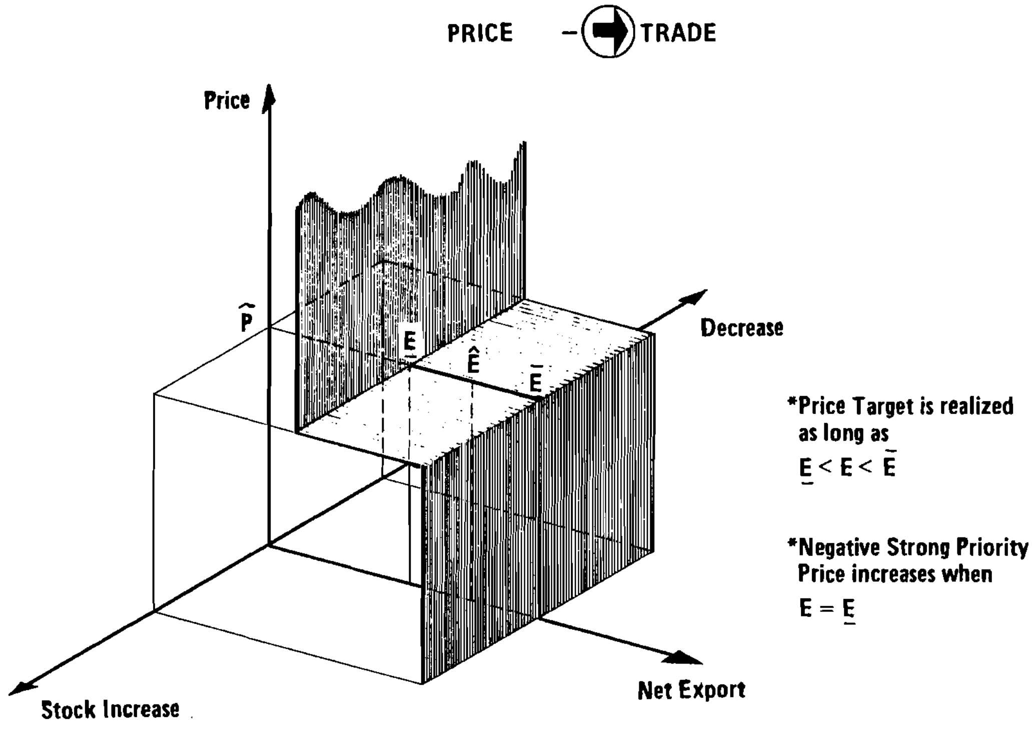

FIGURE 5 Price has a negative strong priority over trade.

Policy adjustment rules should be formulated not only for all commodity markets but also for the financial policy where priorities between tax, trade deficit, and public demand adjustment can be specified. Table 3 lists the policy adjustment rules in the FAP models. It can be seen that the potential of the system has not yet fully been exploited.

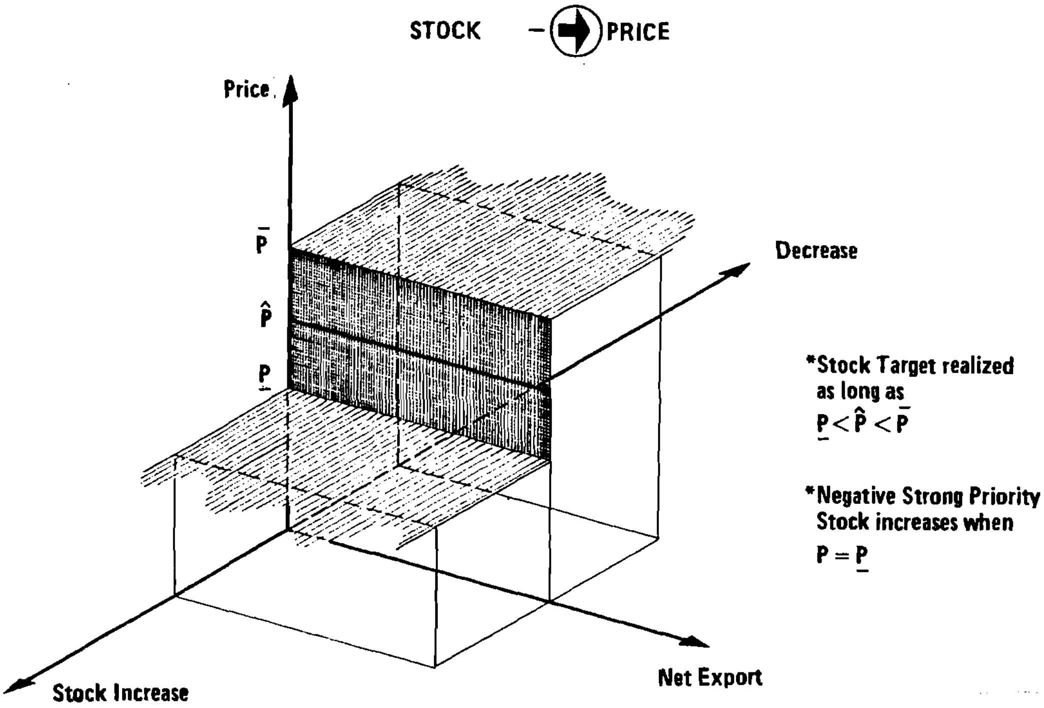

FIGURE 6 Stock has a negative strong priority over price.

2.1.5. International Linkage and International Policies

Now we return to the international level. As illustrated in Fig. 8, all countries are interlinked through their net trade and financial transfers (trade deficits). At given international prices and given national trade deficit the exchange component of each national model is solved in a way which satisfies the behavioral relations for income groups and government as well as the policy adjustment rules specified earlier. Moreover, the national exchange components satisfy the main linkage requirements for a country model. Countries can, however, be linked in different ways depending on the international policies that are assumed to exist.

In the absence of an international agency we merely search for a competitive solution, i.e. for international prices such that world net imports are (nearly) zero for all commodities. Under a buffer stock agreement we introduce additional adjustment mechanisms; a buffer stock agency buys and sells at quoted prices in the same way as within a nation. The essential difference, however, is that at world level trade cannot adjust. We thus have the rules: world net import (=0) → price − → stock − → price. If we segment the world market into two parts through cartel formation, then the countries within the cartel can adjust their overall net export to the rest of the world in order to keep prices to the rest of the world at target level. Within the cartel countries a buffer stock agreement (e.g. to keep the oil in the ground) can take care of undesirable price fluctuations. This yields the policy adjustment rule: price in

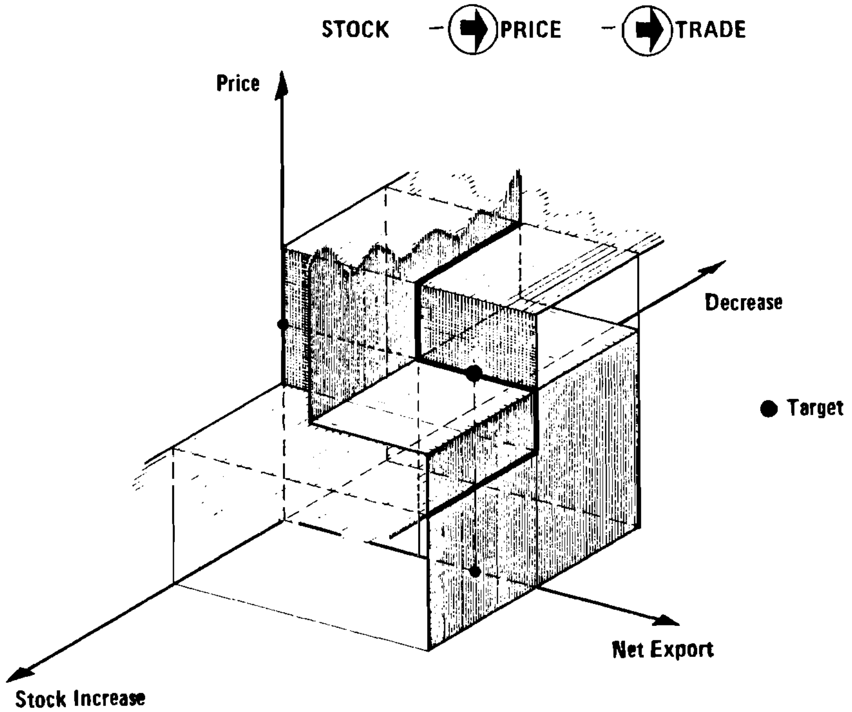

FIGURE 7 Price, stock and trade policy.

cartel – → stock in cartel – → price in cartel – → net export to rest of the world – → price in the rest of the world.

Compensatory financing agreements which imply a specific formulation of the functions which determine international transfers can also be studied in the present model, as well as barter trade agreements (where national productions are redistributed before exchange) and economic unions (where national balances of trade are consolidated).

2.1.6. Computational Complexity of the Model

After having discussed the features of the system let us now briefly discuss the problems involved in actually computing solutions for it. This will not be done with the purpose of elaborating on algorithms but just in order to summarize three basic characteristics.

The first is simultaneity. The simultaneity is a direct consequence of the imposition of accounting rules combined with the feature that the behavior of all actors is described independently. In short, it is a direct consequence of the general equilibrium approach.

The second characteristic is nonlinearity. This again is a direct consequence of the general equilibrium approach because the explicit consideration of financial constraints implies the multiplication of

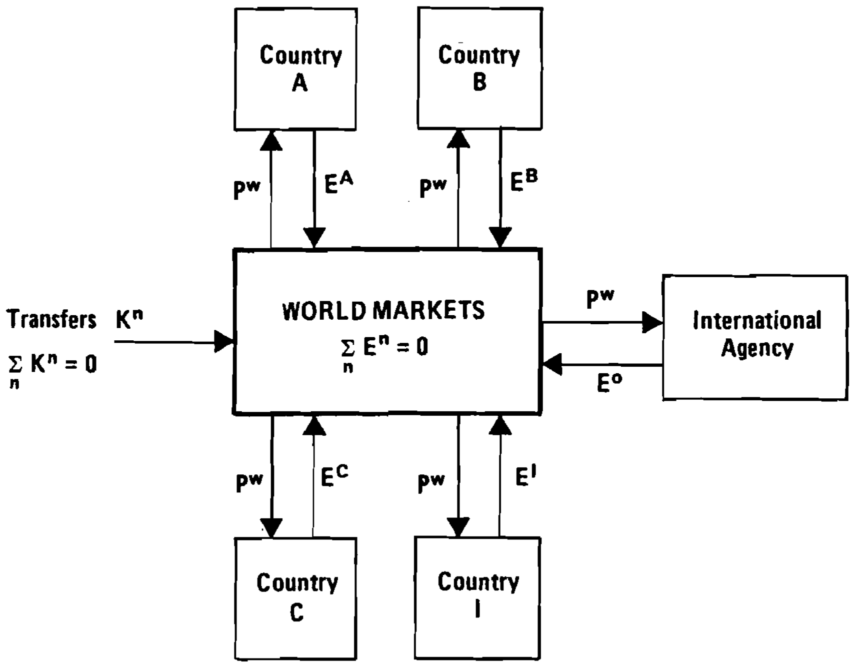

FIGURE 8 International linkage of FAP country models.

TABLE 3 National policies in present FAP models.

1) IIASA "Simplified" (= "Base" = "Mark 2")
   Market: Price –(➡) Trade
   Financial: Trade Deficit (→) Tax

2) US – "Intermediate"; India "Detailed":
   Market: Price –(➡) Stock –(➡) Trade
   Financial: Trade Deficit (→) Tax

3) HUNGARY (HAM–2)
   Market: Price –(➡) Trade
   Financial: Trade Deficit (→) Public Demand^1
   (→) Public Demand^K

unknown prices by unknown quantities in order to obtain values.

The third characteristic is set-valuedness. As explained above, set-valuedness plays a crucial role in the formulation of policy adjustment rules. From a computational point of view it is important to observe (e.g.

in Fig. 4(b)) that when x is set-valued y is fixed and vice versa. Therefore, we can circumvent the set-valuedness by taking x as a function of y on the segments where y as function of x would be set-valued and vice versa. This is commonly called a pivoting procedure.

To illustrate the combined effect of the four characteristics let us come back to the simultaneity issue. There is simultaneity at four levels. First, for each commodity there is a demand–supply simultaneity (even if supply is lagged) owing to the imposition of the supply–demand equality.

Second, since the price of one commodity affects the demand for another commodity and since all commodities must satisfy commodity balances, there is simultaneity among commodities.

Third, since financial balances (accounting rules) also have to be satisfied, there is simultaneity between individual commodities and overall financial constraints (this is actually the most significant difference between partial equilibrium analysis – which looks only at the imposition of commodity balances – and general equilibrium analysis). As mentioned earlier, it is this financial constraint which inevitably introduces nonlinearity.

Finally, the fourth type of simultaneity is the simultaneity among countries. Clearly, one could here again distinguish the three types mentioned above. Figure 9 illustrates the problem of finding a solution, i.e. an intersection point in the presence of our three characteristics as far as the simultaneity at individual commodity level is concerned. Obviously, the actual problem is more complicated owing to the other types of simultaneity.

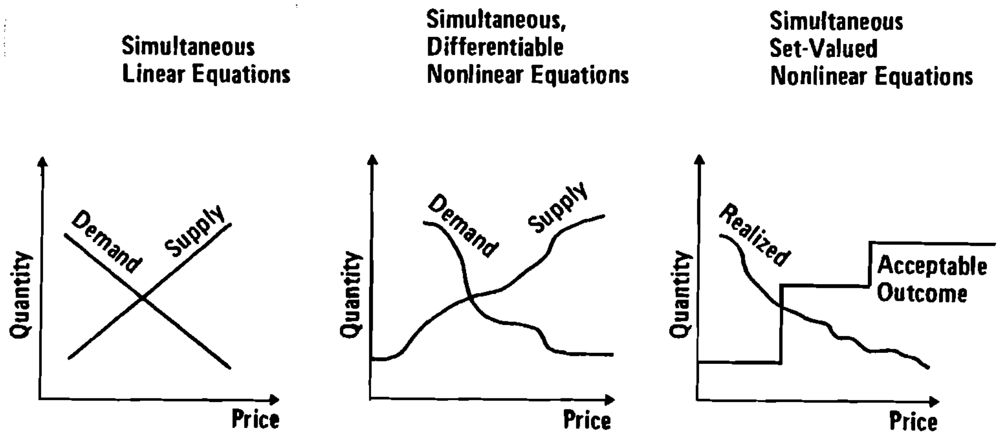

FIGURE 9 Simultaneity for each commodity.

2.1.7. Generalizations and Further Work.

Software has been developed to solve the model outlined here and is currently being used by virtually all FAP researchers. However, since the development and dissemination of analytical tools is an essential objective of the FAP, the methodology must continually be refined and generalized.

At present a version newer than the one described here is available. It possesses the following new features. It is possible to distinguish at the national level between import and export prices for each nation. Monetary variables such as inflation and exchange rates can now be represented. Short-term, demand-driven supply adjustment can be introduced as a phase in the market policy. This is mainly relevant in the nonagricultural sector, which includes services, housing and other commodities with a demand-driven supply.

This brings us to the, as yet unsolved, problem of the optimal disaggregation of the nonagricultural sector. Obviously, energy prices play a role in the food system which is quite different from the role of, say, phosphate prices, and both are linked directly to the nonagricultural sector. To what extent should we consider, in a food and agriculture project, details of nonagricultural commodities? This is still an open question which becomes particularly difficult to answer when it is realized that commodities included in nonagricultural commodities – for example manufactures – are far more heterogeneous than those included in agricultural commodities, such as wheat. This upsets the whole general equilibrium approach, since when commodities are heterogeneous, no meaningful aggregate accounting of commodity balances can be performed and market clearing price formulation becomes meaningless.

2.2. THE BASIC LINKED SYSTEM

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In Part 1 Parikh and Rabár outline the purpose of building the basic linked system and its further application. At the time of the Status Report Conference the basic linked system comprised country models that were mainly updated versions of the simplified models developed by staff members of the FAP (Fischer and Frohberg, 1980). The only countries or country groups for which an independently developed model was linked were the CMEA, Finland, India and the US.

Ideally, the basic linked system should consist of models that are condensed versions of their detailed counterparts. Accordingly, it is intended to replace the models currently included in the basic linked system with condensed versions of the detailed models.

The brief description of the basic linked system which follows refers only to those models developed by FAP members.

The models of the basic linked system fulfill all the mathematical requirements for linking outlined by Keyzer in Section 2.1. They are also consistent with the methodological requirements. We shall briefly discuss some of these.

The models should be built so that they depict perceived realities. In other words, for each country a descriptive model should be set up indicating the responses of the actors in the system to changes in the economic environment brought about by varying terms of trade, policy measures and other factors (e.g. weather shocks). Therefore, the models should be based on empirical information.

Since our aim is to make comparative analyses of policy alternatives over a medium time horizon (15 to 20 years), a correct mapping of the short-term cycle in supply does not receive highest priority. However, the models must have an extrapolative robustness. This is required because some policy measures might be tested which lie outside the historically observed range and for which we should hope to obtain realistic results.

The linkage approach requires that each country model be closed, in the sense that it should cover the whole economy. That is, both the agricultural sector and the nonagricultural sector have to be modeled as well as their interdependences. Given that the emphasis of the study is on food and agriculture, the nonagriculture sector can be depicted only in a highly aggregated way, even for those countries where it comprises 90% or more of total output.

From the point of view of international exchange it would be advantageous if the nonagriculture sector were broken down into at least two commodity aggregates – tradable and nontradable goods. However, in the basic linked system this sector is modeled only as one aggregate.

Since many agricultural products have a production cycle of one year, the model also is run in one-year time increments. The assumption that supply is predetermined when trading occurs leads to a recursively dynamic system.

Each country trades commodities only according to a common commodity classification. How the commodities are aggregated for the basic linked system in comparison with the detailed model system is shown in Tables 1 and 2.

Finally, it is worth mentioning that the medium time horizon envisaged for our policy analysis requires emphasis on modeling the technical input–output relationships of agriculture. The advantage of such an approach is that a consistent mapping between inputs and outputs can be obtained.

Each national model in the basic linked system consists of three main components: a policy module, a supply module, and a demand module. Each module is independently built. The data used for the basic linked system were obtained from various sources, all of which are publicly accessible (see Part 3).

2.2.1. Policy Module

The paper by Keyzer (Section 2.1) describes what types of policies the model is capable of handling for the exchange part and the instruments with which they can be implemented. In addition, those policies which affect producers directly (i.e. not through the exchange part) can easily be considered in the model. For example, measures to stimulate agricultural investment can be included.

From our data sets we can obtain information about the level at which several of these instruments have been set. However, the data do not reveal the policy objectives pursued by using these measures. We therefore refrain from making any ex post policy analyses. Only ex ante investigations of the performances of various policy instruments are being made, with the policy goals given.

At present, the policy instruments are not adjusted endogenously according to the degree with which the objective(s) are reached; rather, the changes in their levels are exogenously determined.

2.2.2. Supply Module

The supply module consists of two components – one for agricultural production and one for nonagricultural production. Owing to a lack of manpower, we made the simplifying assumption that each of the two sectors can be depicted by using the same model structure for all countries.

2.2.2.1. Agricultural production

The level of annual production in agriculture is typically determined in a sequence of decisions arrived at by a large number of decision makers. Since we cannot model this process in its full complexity, we reduced the decision making levels to two. In the first level the quantity of the major inputs to be used in the production activities is decided upon. In the subsequent level these inputs are allocated to the various commodities, and hence the amount of each commodity produced is decided. We also assumed that there is only one decision making unit. This leads to the aggregation of all production units to a "representative farm".

Input levels for the total agricultural sector are determined for labor, capital, and fertilizer. Optimal feed mix is decided upon within the allocation model. All other inputs are assumed to have a negligible allocation effect.

Labor input into agriculture is measured by the number of people employed in this sector. No more precise measure for agriculture manpower could be used owing to lack of data. Such important characteristics as skills and total working hours over a year and during peak seasons could not therefore be taken into consideration.

As labor input function we estimated the following relationships*:

$$\frac{L_t^A}{L_{t-1}^A} = f\left[\frac{GDP_{t-1}^A}{GDP_{t-1}^{NA}} \text{ or } \frac{Z_{t-1}^A}{Z_{t-1}^{NA}}\right] \quad (1)$$

$$\frac{L_t^A}{L_t^T} = f\left[\frac{GDP_{t-1}^A}{GDP_{t-1}^{NA}} \text{ or } \frac{Z_{t-1}^A}{Z_{t-1}^{NA}}\right] \quad (2)$$

where

L_t^A = agricultural labor force in year t (in 1000 persons)

L_t^T = total labor force in year t (in 1000 persons)

GDP_t^A = gross domestic product of agriculture in year t (in million national currency at current prices)

GDP_t^{NA} = gross domestic product of nonagriculture in year t (in million national currency at current prices)

Z_t^A = gross domestic product per agricultural laborer in year t $\left[= \frac{GDP_t^A}{L_t^A}\right]$

Z_t^{NA} = gross domestic product per nonagricultural laborer in year t $\left[= \frac{GDP_t^{NA}}{L_t^{NA}}\right]$

Either the ratio of current to previous year's labor force or the share of total labor working in agriculture was determined. Total labor force is calculated by multiplying the population figure by the participation rate. One explanatory variable used in the labor input function is the ratio of last year's agricultural gross domestic product to that of the nonagricultural sector. This is an approximation of the income ratio of the two sectors. Alternatively, the ratio of the previous year's per capita gross domestic products for the agricultural and nonagricultural labor forces was included; this indicates the income parity of the two sectors.

*All the functions reported in this section are estimated using a nonlinear estimation procedure.

For the labor force, we had to assume that capital is a homogeneous input factor, since lack of data prevented us from differentiating between

TABLE 1 Condensed model commodity list.

Commodity	Unit of measurement
1 Wheat	1000 tonnes
2 Rice, milled	1000 tonnes
3 Other cereals	1000 tonnes
4 Bovine and ovine meats	1000 tonnes[a]
5 Dairy products	1000 tonnes[b]
6 Other animal products	1000 tonnes[c]
7 Protein feeds	1000 tonnes[c]
8 Other food	million US $ (1970)
9 Nonfood agricultural production	million US $ (1970)
10 Nonagricultural production	million US $ (1970)

[a]Carcass weight.
[b]Fresh milk equivalent.
[c]Protein equivalent.

TABLE 2 Detailed model commodity list.

Commodity	Number of aggregate in condensed comm. list	Unit of measurement
1 Wheat	1	1000 tonnes
2 Rice, milled	2	1000 tonnes
3 Other cereals	3	1000 tonnes
7 Bovine and ovine meats	4	1000 tonnes[a]
10 Dairy products	5	1000 tonnes[b]
8 Pork	6	1000 tonnes[a]
9 Poultry and eggs	6	1000 tonnes[c]
13 Fishery products	6	1000 tonnes[c]
5 Protein feeds	7	1000 tonnes[c]
4 Oils and fats	8	1000 tonnes[d]
6 Sugar Products	8	1000 tonnes[e]
11 Vegetables	8	million US $ (1970)
12 Fruits and nuts	8	million US $ (1970)
14 Coffee	8	1000 tonnes
15 Cocoa, tea products	8	million US $ (1970)
16 Alcoholic beverages	8	million US $ (1970)
17 Clothing fibers, hides, and wool	9	million US $ (1970)
18 Industrial crops	9	million US $ (1970)
19 Nonagricultural production	10	million US $ (1970)

[a]Carcass weight.
[b]Fresh milk equivalent.
[c]Protein equivalent.
[d]Oil equivalent.
[e]Refined sugar.

various capital goods. Capital stock is determined in the model in two stages. First, gross investment is decided upon; this is then converted into capital stock data by using

$$K_t^A = K_{t-1}^A(1 - d_t^A) + I_t^A \tag{3}$$

where

K_t^A = capital stock of agriculture in year t (in million national currency at 1970 prices)

d_t^A = depreciation rate for agricultural capital stock in year t

I_t^A = gross investment in agriculture in year t (in million national currency at 1970 prices)

Gross investment in agriculture is described as a share of total gross investment using the relationships

$$\frac{I_t^A}{I_t^T} = f\left[\frac{GDP_{t-1}^A}{GDP_{t-1}^{NA}} \text{ or } \frac{p_{t-1}^A}{p_{t-1}^{NA}} \cdot \frac{GDP_{t-1}^{A,CO}}{GDP_{t-1}^{NA,CO}}\right] \tag{4}$$

where

I_t^T = total gross investment in year t (in million national currency at 1970 prices)

$GDP_t^{A,CO}$ = gross domestic product of agriculture in year t (in million national currency at 1970 prices)

$GDP_t^{NA,CO}$ = gross domestic product of nonagricultural sector in year t (in million national currency at 1970 prices)

p_t^A = price index of agricultural commodities in year t

p_t^{NA} = price index of the nonagricultural commodity in year t

All other variables are as defined above.

Agricultural investment share is determined by using two different types of explanatory variables. According to one relationship, it is a function of the ratio of the previous year's agricultural to nonagricultural gross domestic product. Alternatively, the share of investment in agriculture is explained by the ratio for the previous year of the agricultural and the nonagricultural price indexes and by the previous year's ratio of the outputs of the two sectors.

Total gross investment is estimated as a function of the total gross domestic product at current prices, the trade deficit, and the change in gross domestic product between the previous year and the year before that; that is

$$I_t^T = f(GDP_{t-1}, BAL_{t-1}, DGDP_{t-1}) \tag{5}$$

where

GDP_t = total gross domestic product in year t (in million national currency at current prices)

BAL_t = trade deficit in year t (in million national currency at current prices)

$DGDP_t = GDP_t - GDP_{t-1}$

Concerning fertilizer inputs, we assumed that nitrogen, potash, and phosphorus are applied in fixed proportions; hence it suffices to consider nitrogen alone as a variable. However, the unit value of nitrogen is then not just the nitrogen price but includes the value of potash and phosphorus applied together with each unit of nitrogen. The functions estimated for determining the fertilizer input level are as follows:

$$TF_t = f\left(\frac{1}{p^r_{Ft}},\ ICROP_{t-1} \text{ or } \frac{p^C_{t-1}}{p^{NA}_{t-1}},\ \frac{1}{p^r_{Ft}},\ ICROP_{t-1}\right) \qquad (6)$$

where

TF_t = total fertilizer (nitrogen) bought by agricultural sector in year t (in 1000 tonnes)

$ICROP_t$ = crop production in year t (in million national currency at 1970 prices)

p^C_t = price index of crops in year t

p^{NA}_t = price index of the nonagricultural commodity in year t

p^r_{Ft} = relative unit value of fertilizer in year t, calculated as the ratio $p_{Ft}/(p^{NA}_t/p^{NA}_{70})$ with p_{Ft} being the unit value of fertilizer in year t

According to this specification, fertilizer input can be explained by the level of last year's crop production and the relative unit cost of fertilizer. In addition to depending on these two variables, fertilizer input also is determined by the ratio of last year's price indexes for crops and for the nonagricultural sector.

For the second decision making level – the allocation of the inputs – a nonlinear programming model with a nonlinear criterion function and linear inequality constraints is used. The parameters of this allocation model are statistically estimated, with the exception of those coefficients which are used to determine the level of individual commodities in the case of joint production. The values of these coefficients are obtained from national accounts and engineering information.

The allocation model can be written for any year t as follows:

$$\max_{F_{it}, K_{it}, L_{it}} Z_t = \sum_i nr_{it} \cdot Y_{it}$$

$$\text{s.t.} \sum_i F_{it} - F^A_t \le 0$$

$$\sum_i K_{it} - K^A_t \le 0$$

$$\sum_i L_{it} - L^A_t \le 0$$

with

$Y_{it} = \alpha_{it} \cdot K^{\beta_i}_{it} \cdot L^{\gamma_i}_{it} \cdot F^{\eta_i}_{it}$ for each i

$\beta_i + \gamma_i + \eta_i \le 1$ for each i

$\eta_i = 0$ for $i \in$ animals

where

i	= commodity index (for description see Table 1)
t	= time index
Y_{it}	= net production of commodity i in year t (gross production minus seed use and waste)
K_t^A	= capital stock in agriculture in year t
L_t^A	= labor force in agriculture in year t
F_t^A	= fertilizer input in year t
K_{it}	= capital employed in production of commodity i in year t
L_{it}	= labor employed in production of commodity i in year t
F_{it}	= fertilizer applied to crop i in year t
nr_{it}	= (if $i \in$ animals) net revenue per unit of commodity i in year t defined as expected price minus feed cost = (if $i \in$ crops) expected price of commodity i in year t
α_{it}	= a term taking account of technical progress in either an embodied or a disembodied (with a trend variable) way

By solving the allocation model, we obtain an optimal (with respect to the criterion function) use of the (predetermined) total inputs of fertilizer, capital, and labor, and simultaneously the net production of each commodity. The latter is treated as supply.

For obtaining expected prices we assume that farmers have naive price expectations; in other words, that prices received by farmers in the previous year are taken as expected prices for the current year.

The calculation of feed cost per unit of animal product includes only feed concentrates. Roughage is not yet considered in the model. Feed costs are obtained by summing the products of the requirements for feed concentrates per unit animal product and the corresponding feed prices. The functional relationships used to determine the feed requirements are obtained from the first-order conditions of a model which minimizes feed costs. These relationships are of the following form:

$$a_{ikt} = f(r_{1t}, \cdots, r_{8t}, t) \qquad (7)$$

where

a_{ikt}	= requirement of feed concentrate k per unit of product i in year t, for $i \in$ animals $k = 1,\ldots,8$
r_{kt}	= price of feed concentrate k in year t
t	= time variable

The time variable used in this function is a proxy for measuring the change in the (technical) efficiency in feeding. At present, we have not incorporated any constraints reflecting nutritional standards.

The basic assumption underlying this feed mix model is that the supply of feed concentrates is completely elastic. The optimal feed use per unit of animal product is therefore independent of the size of the livestock sector and can be determined prior to solving the allocation model.

2.2.2.2. Nonagricultural production

As mentioned above, the nonagricultural sector is aggregated to one commodity. This sector is represented by a Cobb–Douglas production function, i.e.

$$Y_{nt} = \alpha_{nt} \cdot K_{nt}^{\vartheta} \cdot L_{nt}^{1-\vartheta} \tag{8}$$

where

Y_{nt} = nonagricultural production in year t

K_{nt} = capital stock of the nonagricultural sector in year t

L_{nt} = labor force in the nonagricultural sector in year t

α_{nt} = a term which includes neutral technical progress measured by a trend variable

We assumed that capital stock is always fully utilized and that there is no unemployment. The amount of capital and labor engaged in nonagricultural production is calculated as the difference between the total availability for the whole economy and that employed by the agriculture sector.

2.2.3. Demand Module

The demand for goods is modeled in the basic linked system by using an extended linear expenditure system (ELES). We distinguish two income classes for developing countries and one for developed countries. In the case of two income classes the criterion for differentiating between these classes is occupation. Those people who work in agriculture and their dependents are grouped into one class and others into the second class. This procedure had to be followed since we do not have statistics on the numbers in various income classes.

We tried to estimate the coefficients of the extended linear expenditure system but obtained unrealistic results. We therefore followed a more pragmatic approach. In an extensive literature search, average expenditure shares for each country – and, where necessary, for each income class – were collected. Together with information on expenditure shares at farmgate level, these expenditure shares at the retail level were taken to determine the value of processing, marketing and distribution per unit of each commodity (hereafter called the processing margin). The processing margin is kept constant over time.

We also estimated expenditure elasticities for each commodity by fitting a nonlinear Engel curve to the time series data of the corresponding per capita expenditure. These expenditure elasticities were then used to obtain the coefficients for marginal budget shares along with committed consumption by the following steps.

Given supply, to enter exchange it is assumed that agricultural production is owned by the agricultural income class and that nonagricultural production is owned by the nonagricultural income class. Using expected prices we can calculate expected income for each income class. In the second step this expected income is split into expected expenditures on agricultural goods and nonagricultural goods by means of a two-sector dynamic linear expenditure system (DLES). Then expected expenditures spent in total on agricultural goods are further subdivided into expected expenditures on each of the nine agricultural commodities using the corresponding expenditure elasticity.

Once the demand at expected prices has been calculated for each of the traded commodities, this information is translated into the parameters of the ELES in the following way.

$$TEXP^j = \overline{\varphi} \cdot \sum_i^n \hat{P}_i \cdot YM_i^j$$

$$e_i^j = \eta_i^j \cdot \frac{EXP_i^j}{TEXP^j} \qquad i = 1, \cdots, n-1$$

$$e_n^j = 1 - \sum_{i=1}^{n-1} e_i^j$$

$$XM_i^j = [EXP_i^j - e_i^j \cdot (TEXP^j - COMEXP^j)] / \hat{P}_i \qquad i = 1, \cdots, n$$

where

η_i^j	= expenditure elasticity of commodity i for income class j
EXP_i^j	= expected expenditure on commodity i by income class j (expected target retail price multiplied by expected consumption)
$TEXP^j$	= total expected expenditure by income class j
$COMEXP^j$	= committed expenditures by income class j at expected prices (obtained from two-sector DLES)
$\hat{P}_i$	= domestic target retail price of commodity i
XM_i^j	= committed consumption of commodity i by income class j
e_i^j	= marginal budget share of commodity i by income class j
$\overline{\varphi}$	= 1 − expected tax rate
YM_i^j	= endowment of commodity i by income class j

Both feed use and intermediate consumption of each commodity are included in the demand module. Their values are added to the committed demand coefficient of the corresponding product.

It remains for us to explain briefly how the solution of the demand system is obtained in the exchange component.

The exchange component depicts the simultaneous market relationships, that is, the national response to changing world market prices. In the linkage the iterative calling of all the national exchange modules in sequence continues until international equilibrium is achieved.

More specifically, the purpose of the exchange routine is as follows. We start with given vectors of world market prices, PW; of supply, Y; of endowments for each income class, j, YM^j; and with a set of policy targets – namely, vectors of minimum and maximum national consumption, $\underline{X}$ and $\overline{X}$ respectively, as well as a target of trade deficit, BAL. The exchange routine finds a level of realization of the targets such that the following conditions hold (since these conditions hold for any year, we drop the time index):

$$PWD_i = PW_i + PRM_i \cdot PW_n \qquad i = 1, \cdots, n-1$$

$$P_i = \hat{P}_i + P_i^+ - P_i^- \qquad i = 1, \cdots, n$$

$$\hat{P}_i = \alpha_i \, PWD_i \qquad i = 1, \cdots, n$$

$$P_i \cdot X_i^j = e_i^j \cdot \sum_{k=1}^{n} P_k \cdot (\varphi \cdot YM_k^j - XM_k^j) + P_i \cdot XM_i^j \qquad \begin{cases} i = 1, \cdots, n; \\ j = 1, \cdots, nc \end{cases}$$

$$X_i = \sum_{j=1}^{nc} X_i^j \qquad i = 1, \cdots, n$$

$$\text{s.t. } \underline{X}_i \le X_i \le \overline{X}_i \qquad i = 1, \cdots, n$$

$$(\overline{X}_i - X_i) \cdot P_i^+ = 0 \qquad i = 1, \cdots, n$$

$$(X_i - \underline{X}_i) \cdot P_i^- = 0 \qquad i = 1, \cdots, n$$

$$\sum_{i=1}^{n} PW_i \cdot X_i = \sum_{i=1}^{n} PW_i \cdot Y_i + BAL$$

Description of symbols:

i,k	= commodity-specific indexes (see Table 1)
j	= income class specific index
n	= total number of commodities
nc	= total number of income classes
PRM_i	= amount of processing (nonagriculture commodity) required per unit of commodity i
PWD_i	= world market price at retail level of commodity i
PW_i	= world market raw material price of commodity i
$\hat{P}_i$	= domestic retail target price of commodity i
P_i	= realized domestic retail price of commodity i
X_i^j	= consumption of commodity i by income class j
X_i	= total consumption of commodity i
e_i^j	= marginal budget share of commodity i by income class j
XM_i^j	= committed consumption of commodity i by income class j
Y_i	= supply of commodity i
YM_i^j	= endowment of commodity i by income class j
$\underline{X}_i$	= lower limit on consumption of good i
$\overline{X}_i$	= upper limit on consumption of good i
P_i^+	= upward deviation of realized price from target price due to upper limit on consumption for commodity i
P_i^-	= downward deviation of realized price from target price due to lower limit on consumption for commodity i
α_i	= 1 + tariff rate on commodity i
BAL	= trade deficit

φ = 1 − tax rate

More details about obtaining a solution for the model described above by using a complementary pivoting technique are given by Keyzer (1980).

The solution of the exchange component contains among other variables a vector of total demand for each income class. In a final calculation each element of this demand vector is split into human consumption, feed use and intermediate consumption by using the information on the latter two items we obtained from the supply module.

2.2.4. Validation

The model is validated in a hierarchical way following the steps in building the model. The first validation step was done while each subcomponent of the model was set up. Here we relied on such criteria as fit of estimated variables, t-test of estimated parameters, test for autocorrelation, and plausibility of the parameters.

The next validation phase took place when the individual subcomponents were linked together. We added together subcomponent after subcomponent, and each time checked the fit of all endogenous variables. At each step of adding a new subcomponent we have a larger set of endogenous variables. Hence, the problem of weighing the fit of those variables arises. We did not employ a formal procedure but used subjective judgment. At the last step, the linking of all national models, we placed heavy emphasis on net trade figures for each country and the world market prices for evaluating the performance of the basic linked system.

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2.3. POLICY INSIGHTS FROM THE BASIC LINKED SYSTEM

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At the present stage of research it is too early to speak about insights. We have just had results of the first policy runs with the linked system, and now debugging and improvement of the program and further validation and sensitivity analysis are required to generate more reliable results. What we present here is just an illustration of the methodological papers and is not an analysis of real-world data. Even slight changes in the assumptions about the behavior of the rest of the world (which is not modeled in a detailed way) might bring about qualitative changes in the results. The present run, though, is instructive in showing some "counter-intuitive" features of the system.

When estimating the future needs of mankind, many projections for the year 2000 (OECD, 1979; FAO, 1979) claim that for the eradication of hunger for about 300 million people we would need an extra 20 to 32 million tons of grain annually. This amount could prevent hunger if it reached the right people. Table 1 gives an idea of the magnitude of this quantity.

Many people are misled by numbers like those in the table into proposing simplistic solutions which do not take into account the complex system behind the data. As typical examples: "A 2.5 billion dollar pet-food business to keep 150 million dogs and cats healthy...do our politicians have the fortitude to run a platform of No More Pets and Fewer Zoos? or Austerity Here to Save Lives Elsewhere?" (Holman, 1978). We come across similar statements in relation to the consumption of meat in the rich countries, or of any other luxury items. Yet this approach can only be a part of the solution. A pure abdication, an asceticism, however sincerely practiced, remains an individual act, since it does not change the mechanism of a system based on different moral principles.

In contrast to such simplistic approaches, the different items in Table 1 are not intended to be suggestions how to eradicate hunger. In fact – as will be shown – even more direct transfers would not suffice to meet this requirement. The comparisons show just how marginal the quantity needed is. This makes the problem we face even more mysterious: why are we still unable to solve this problem if so little effort is required? Why can we not redirect 1.4% of world grain production to the poor who need it? Is it not possible to influence the present market mechanism slightly to reach this goal?

There is some evidence to show that world food grain prices are kept high by the government policies of some big exporters and that this

TABLE 1 Grain equivalents of various expenditures, for the purposes of comparison.

Expenditure	Grain equivalent (approx.)	Data source
2.5 billion $ pet-food business in US	18 million tons	Holman (1978)
Loss of grain production caused by the fertilizer shortage after 1973 energy price increases	15 million tons	Chancey (1978)
Three days' world military budget	20 million tons	OECD (1979)
US mass media food advertising	18 million tons	USDA
1.4% of world grain production, 1976	20 million tons	FAO (1979)
To produce an additional 20 million tons per year in developing countries, 11 billion $ investment is needed annually for 15 years		Mellor (1979)

prevents poor countries from importing more. Thus, not just prices but also hunger are kept at a given level. What would happen if we kept prices low and allowed the poor countries to import more than they do now?

This is one of the questions we should like to have answered in the future, when our model system is ready for it. One of our first runs was organized accordingly, and the results were certainly surprising.

As a first step we assumed that a hypothetical country enters the market with the firm intention of selling 30 million tons of wheat each year, at any price, to help poor importers.

A new additional input channel that does not follow the rules of the market is thus opened in the system. It continues supplying just the missing amount of grain, that needed to eradicate hunger.

A series of adjustments starts as soon as the first 30 million tons appear on the market. The international market response is instantaneous. Argentina, Australia, Canada, the US, Mexico, and India reduce their exports of wheat, and Austria, Japan, Brazil, Egypt, New Zealand, the EC, Thailand, Kenya, Pakistan, Nigeria, and the rest of the world increase their imports. The CMEA countries, China, and Indonesia show no reaction. Yet the quantity is too high to be completely absorbed at prevailing prices. The wheat price drops and it stays depressed for the next ten years (Fig. 1).

The second-level adjustment on the part of the exporting countries, after reducing their exports, is reducing their production as well. This happens with different time lags, different speeds and different intensities. This is, though, the general response of all the exporters.

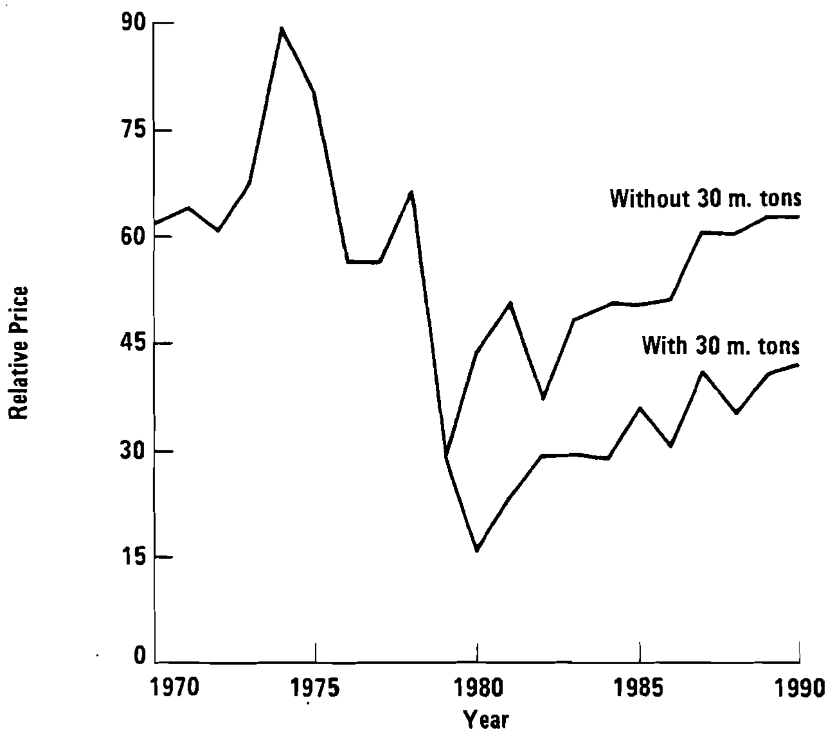

FIGURE 1 Wheat market response.

There are some exporting countries where this response is more particular and somewhat unexpected. India, which is surprisingly a net exporter in these runs, is affected like other exporters. It reduces its wheat exports and even becomes a modest wheat importer. The human consumption of wheat goes up and rice consumption is affected only slightly. As a result, as far as total population figures are concerned, per capita consumption increases slightly. However, the distribution among the income classes is remarkable in that there is a clear decline in the daily calorie intake of the urban population, while the rural population is better off. (There is a shift in the GDP in favor of agriculture as well.) This shows that if domestic policy measures do not adjust to the changed international situation, even a favorable change might affect a large sector of the population. Without an internal redistribution the lowest urban income classes would suffer heavily under the new conditions.

The reaction of the US is also remarkable. The US does not differ from other exporters as far as the export reduction is concerned. However, its present stock policy heavily influences its reaction. The buffer stock response (an important part of US policy) exceeds the quantity by which exports are reduced; thus production is kept on a high level. The domestic consumption of wheat increases mainly for feed purposes but also marginally for human consumption. Thus – according to the present agricultural policy representation – the US alone among the exporters raises its supply even with decreased international prices.

The second-level adjustment on the part of the importers, after increasing their imports and their home demand, is the reduction of their home supply. In other words, they substitute their home production with cheap imports. Of course, they reallocate their production capacities to other products: Brazil mainly to bovine and nonfood agricultural production, Egypt to bovine and rice production, and New Zealand to bovine and dairy production. Because of these substitutions the consumption of wheat increases only marginally, and hungry people do not eat much more.

A slight improvement in the nourishment of the population can be observed in Pakistan, Nigeria and Egypt, yet Kenya and Mexico are worse off. The real advantage seems to be in the beef market. In almost all countries there is an upward shift in the feed consumption: either wheat is directly used as feed or producers substitute wheat with coarse grain production. Bovine production and export figures in the exporting countries and imports in the importing countries go up and for some years after the shock an upswing in the beef market is created, until prices and production begin to adjust.

After all these adjustments we may ask the question: where are the additional 30 million tons of wheat, put on the market by an imaginary country? The answer is that it was absorbed in the system. Almost none of it reached the hungry people of the countries represented. Part of it certainly disappeared through the leakage created by the rest of the world under the present specification. Yet, although the impact of the rest of the world can be made larger or smaller, it does not change the behavioral rules of the countries represented. According to these rules, they increased their buffer stocks, they changed their export structures and they substituted their wheat production with feed grain, bovine, dairy and nonfood production. Consequently, hunger was not eradicated; instead a new export and production structure was created that seemed more profitable from the point of view of the new relative prices. The present market mechanism did not solve the problem. A solution by the market could not have been rationally expected anyway, since we already knew that effective demand does not reflect a considerable part of biological needs, and that the market is distorted in many ways by conflicting agricultural policies.

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2.4. THE GAME THEORETIC APPROACH

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Game theory studies situations of social conflict where there are at least two parties with conflicting interests and more than one possible course of action. It is essential that the payoff for a particular action of a party strongly depend on the choices of action of its opponents.

Generally the payoff for an individual farmer or consumer is not essentially affected if another farmer or consumer changes his behavior. That is why we do not usually consider farmers or consumers as players interacting on national or even international food markets. Nevertheless, there is a great deal of strategic interaction on international food markets. The main reason is that in many countries governments try in various ways – either directly or with the help of marketing boards – to influence market results. If the government of a country that is an important importer or exporter of some food products changes its policy, for example its import or export tariffs and/or quotas, there are often serious consequences in other countries. Thus when determining their agricultural policies the governments – at least those of the important food importing and exporting countries – find themselves in a game situation. The main intention of our game theoretic approach is to derive optimal agricultural policies by defining payoff functions for the governments of such countries and applying game theoretic solution concepts.

2.4.1. General Overview

It is an obvious idea to complement the system of simplified models developed by the Food and Agriculture Program at IIASA with payoff functions for the governments and to consider the new system as a game. A strategic analysis would certainly yield deep insights into which policies should be chosen when reactions of other countries are anticipated. Unfortunately, however,the FAP linked system model becomes a very complicated game when complemented with realistic payoff functions. Because of the enormous complexity of the FAP linked system (even the "simplified" models are, with 10 commodities, quite detailed and complex), there would be little hope of getting results within a reasonable time.

Thus from the very beginning it was clear that the strategic analysis of the FAP linked system would have to rely on simplification. One possibility is to approximate the models of the linked system by models of a simpler mathematical structure. This has been and will be done when the strategic interaction in time is studied with the help of dynamic game models (see section 2.4.3 on dynamic interaction models). Another possibility is to distinguish only two commodities, food and nonfood; i.e., just one agricultural product instead of many. The advantage of this approach is that we can still learn what is implied by the mathematical structure of the FAP linked system, since we can always aggregate the other products to one residual commodity. When following this approach, the future effects of present decisions have been considered only in a nonstrategic way (see section 2.4.2 on static interaction models).

Especially because of the various ways in which governments try to influence market results, international food markets are interesting for game theoretic research. International trade theory is here of little help since it usually neglects policy variables such as national buffer stocks or domestic consumer and producer prices. Furthermore, the few strategic studies mostly rely on unrealistic payoff functions. Thus we came to the conclusion that international trade theory can and should be further developed by studying international food markets. Especially, we want to investigate the economic results under various institutional setups – for instance, different forms of international cooperation. Studies along these lines are planned and have already been initiated in cooperation with IIASA's methodology group, the System and Decision Sciences Area (SDS); these cannot be described in detail here, however.

2.4.2. Static Interaction Models

This work was started in cooperation with Reinhard Selten of the University of Bielefeld, FRG. First the models of the FAP linked system were replaced with very simple models with only two commodities – food and nonfood. Different versions of this system have been investigated analytically; for example, we analyzed a system in which trade deficits are determined endogenously. The main result is that under plausible conditions it always pays to supply as much food as possible. The elasticity of demand for food is obviously due to the specification of demand by linear expenditure systems (see Selten and Güth, 1981).

The analytic results made it interesting to determine econometrically under more general assumptions whether or not it pays to supply as much food as possible. In cooperation with Günther Fischer and Jan Morovic of the Food and Agriculture Program at IIASA, four different model structures have been estimated and analyzed according to their incentives for maximal food supply decisions. In two cases trade deficits were either exogenously given or endogenously determined by use of national absorption functions. In the other cases it has been distinguished whether or not food supply entails essential processing costs. The empirical findings threw some doubt on the previous analytic results. Especially when we allow for processing costs of food and consider trade deficits as exogenously predetermined, it is not generally optimal to supply as much food as possible (a more accurate account of the results will be given in a forthcoming working paper by Fischer, Morovic, and Güth).

Because of the empirical findings,we have to expect that some countries will sell as much food as possible on the international markets, whereas others will choose to sell smaller amounts. To compute such solutions, computational procedures (algorithms) have to be designed that determine endogenously which countries will be bound by their constraints and which countries will choose intermediate strategies. This task has essentially been accomplished, mainly by Andrzej Wierzbicki of IIASA's methodology group (SDS). The algorithms will be applied to the four estimated models already described.

2.4.3. Dynamic Interaction Models

Owing to the production lag in agriculture in relation to investment decisions and buffer stocks, present decisions have important consequences for future food markets. Accordingly governments, when determining their agricultural policies, should consider how their present decisions affect the future market. This market therefore has to be modeled as a dynamic and not as a static game. To do this, the mathematical structure of the linked system has to be changed slightly. Some of the conceptual problems have already been resolved, but the games have not been solved and estimated so far.

On food markets, tendencies to form boards by which the major sellers try to "stabilize" markets are often observed. Mostly this is done by price agreements and by the use of buffer stocks to control total supplies. In cooperation with Bozena Lopuch of the FAP group at IIASA, we have attempted to explore the effects of such activities with the help of dynamic game models for single-food markets. An interesting result is that it makes quite a difference whether one country – probably the major seller of that product – is asked to control supply by buffer stock adjustments and price recommendations, or whether this is done by founding a buffer stock agency (an extensive economic discussion will be given in a forthcoming paper by Lopuch and Güth). The econometric estimation has not yet been started. We should like to explore more models before we decide which should actually be estimated.

Reference

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PART 3. THE FAP DATA BANK

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3.1. Introduction

The FAP modeling work includes a variety of types of activities, such as parameter estimation, equation definition, model design, model running, calibration and validation, and hypothesis testing. These interrelated activities make use of different tools and resources available either at IIASA or through the FAP's collaborating institutions.

One of the essential resources is data, in the form of time series on agriculture and other aspects of the economy. The FAP has created the FAP data bank, a large set of sequentially organized time series which are sorted by codes and stored in computer-readable form.

3.2. Sources

The FAP data bank has been put together from various sources that provided data of two types: computer-readable data and "human-readable" data.

In mid-1978 we received from the UN Food and Agriculture Organization (FAO) in Rome the first magnetic tapes with time series from the Production and Trade Yearbooks, including data on the production and trade of agricultural commodities and fishery products.

Shortly afterwards the International Labour Organization (ILO) in Geneva sent a magnetic tape with population and labor force estimates and projections for all its member countries. The period covered was from 1950 to 2000, in five-year steps, so we had to make some calculations in order to have a complete time series.

At the same time the World Bank in Washington DC made available the World Tables on magnetic tape, for the years 1961 to 1976, with macroeconomic data on about 100 developing countries. These tables, together with similar information on the developed countries, on another set of magnetic tapes from Amsterdam, provided a good coverage of the world in terms of macroeconomic indicators.

The greatest efforts and interest were invested in the Supply Utilisation Accounts (SUA), also from FAO and also on magnetic tape, because these accounts represent in detail a complete flow of agricultural products in the chain between production (e.g. farmer) and final consumption (e.g. by households, industry, or animals). Figure 1 shows schematically how the accounts are set up.

Owing to the volume of these data it was not feasible to include the

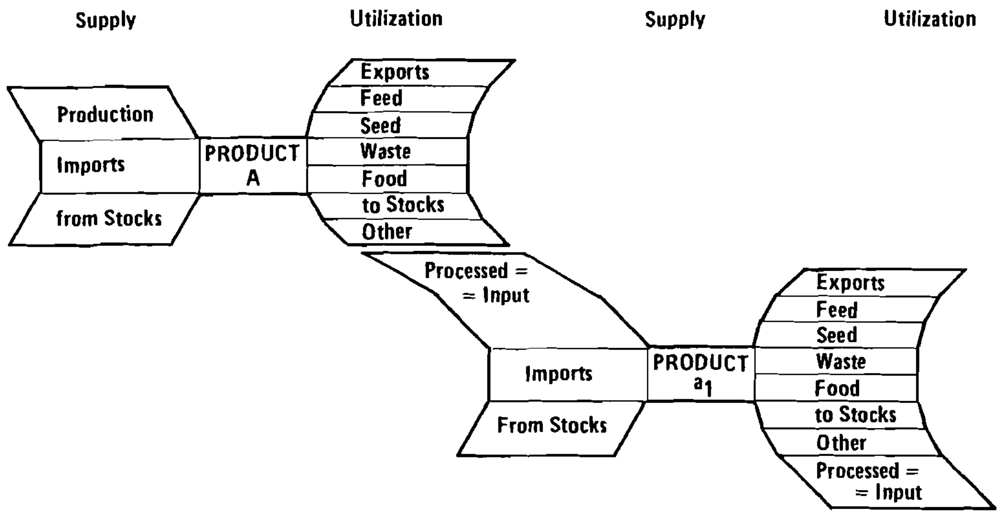

FIGURE 1 The organization of the Supply Utilisation Accounts.

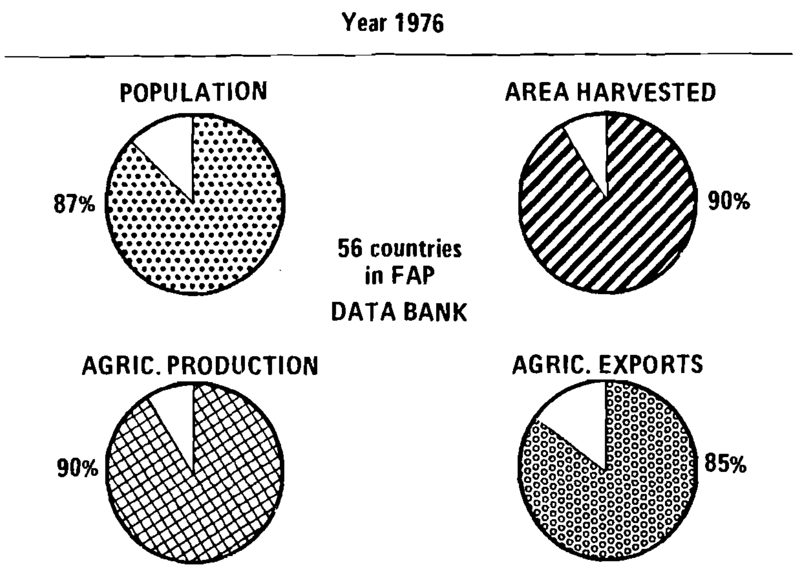

FIGURE 2 The world coverage of the FAP data bank.

SUA for all countries dealt with at FAO. Only the 56 largest countries in terms of production, trade and consumption were selected (see Fig. 2 and Table 1).

Considerable effort was invested in finding figures for other indicators of agriculture and the economy in general, such as fertilizer use, prices of goods, expenditure shares or capital stocks. The "human-readable" sources, such as different publications from international

TABLE 1 Countries covered by the FAP data bank.

EC and Japan	*CMEA Countries*	*Rest of Europe*
Belgium–Luxemburg	Bulgaria	Austria
Denmark	Czechoslovakia	Finland
France	GDR	Greece
FRG	Hungary	Norway
Ireland	Poland	Portugal
Italy	Romania	Spain
Japan	USSR	Sweden
Netherlands		Switzerland
UK		Turkey
		Yugoslavia
Developing Africa	*Developing Asia*	*Latin America*
Algeria	Bangladesh	Argentina
Egypt	India	Brazil
Ethiopia	Indonesia	Mexico
Kenya	Iran	Peru
Morocco	Iraq	Venezuela
Nigeria	Korea, DPR	
Sudan	Pakistan	
Syria	Philippines	
Tanzania	Thailand	
Tunisia		

organizations, national statistics, and books, were consulted in order to complete our data bank.

3.3. SUA and Aggregations of the SUA

The Supply Utilisation Accounts are a very important source of information for the FAP modeling work because it is possible to trace in detail the supply and demand of agricultural goods, not only for natural products such as maize, apples or cattle, but also for processed or derived products such as starch, canned fruits or sausages. The agricultural models developed at IIASA do not have as detailed a commodity classification as FAO reports in its SUA. It was therefore necessary to arrive at a much more general commodity classification which could be used in the national models. The classifications used in the simplified and detailed models are given in Part 4.

A number of computer programs were developed at IIASA, and, using suitable aggregation weights, the steps shown in Fig. 3 were carried out for each of the 56 countries for which we have the SUA figures.

3.4. Organization

The considerations involved in organizing our data in sequential form were as follows:

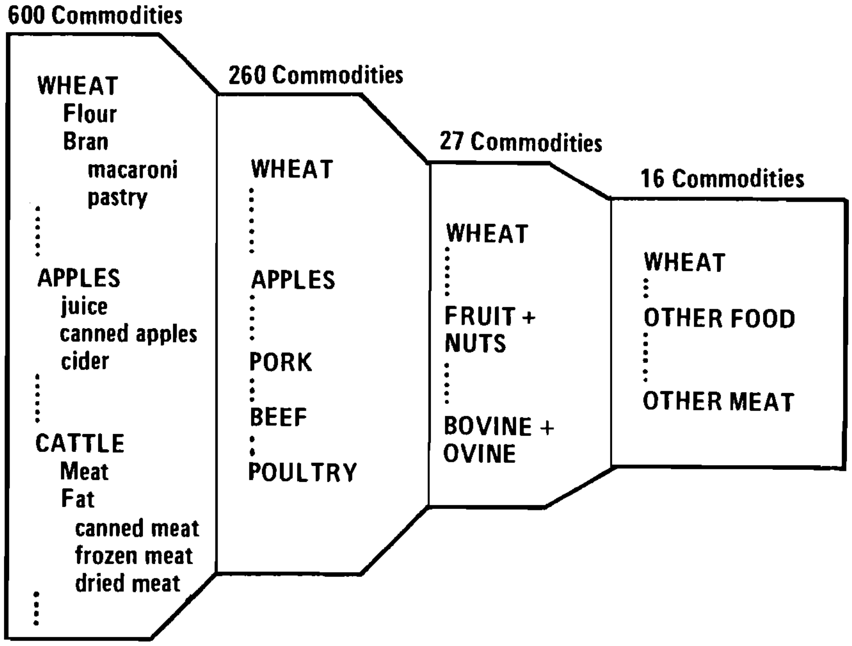

FIGURE 3 Aggregation steps of the Supply Utilisation Accounts.

- the data should be easily transferable from IIASA to any of the collaborating institutions
- a universally available computer language should be able to handle the data
- as few conversion routines as possible should be needed to create our data bank from already existing computerized time series

Thus the FAP data bank is organized similarly to the FAO data, in sequential order by increasing code number. Each data record has a code field with seven entries, and a data field with 16 entries (one for each year of the time series). It is of course possible to extend the data field to allow for further years, but at present data for only 16 years can be stored (for most of the data, the years 1961 to 1976).

The seven entries of the code field are:

1	internal system code
2	country code
3	commodity code
4	element code
5	dimension code
6	first year indicator
7	data entry date

In the data field, each of the 16 year entries also has an indicator giving information on the quality of the data. Owing to the complexity of the aggregation and to all the corrections and additions made in the course of

TABLE 2 Coded time series from the SUA.

23	101	3502	3	1	61	9999	6857000.	7283000.	6731000.	...
							8014000.	8135000.	8324000.	...
23	101	3502	4	2	61	9999	11806.	11962.	11556.	...
							15065.	15921.	16249.	...
23	101	3502	5	2	61	9999	8095644.	8712023.	7778209.	...
							12072981.	12951415.	13525818.	...
23	101	3502	5	3	61	480	9.	28.	61.	...
							23078.	27107.	27766.	...
23	101	3502	6	2	61	9999	927751.	955910.	937825.	...
							527298.	833883.	443485.	...

TABLE 3 Decoded SUA time series from Table 2.

23 101 3502			indonesia		rice S2	
			1961	1962	1963	...
item	unit	yy	1969	1970	1971	...
31		61	6857000.	7283000.	6731000.	...
area harv	ha	69	8014000.	8135000.	8324000.	...
42		61	11806.	11962.	11556.	...
yield	*kg/ha	69	15065.	15921.	16249.	...
52		61	8095644.	8712023.	7778209.	...
production	mt	69	12072981.	12951415.	13525818.	...
53		61	9.	28.	61.	...
production	unit.p	69	23078.	27107.	27766.	...
62		61	927751.	955910.	937825.	...
imports	mt	69	527298.	833883.	443485.	...

the development of the data bank, we have omitted these indicators for the SUA in its aggregated versions.

The data records are stored in binary form on different devices, and are accessible with special FORTRAN programs. All data are kept on magnetic tapes and can be retrieved from these on request. The most frequently used time series are at the same time available on-line on our in-house computers.

As the data bank is organized sequentially, it is not necessary to have all time series merged in the same file. The data are divided into groups, such as Supply Utilisation Accounts of a certain level of aggregation, macroeconomic data, labor force data, and national producer prices.

Naturally there are procedures available that can, for example, extract, merge, delete, or add time series, or produce readable outputs, calculations, or plots of different types. All these routines are also written in FORTRAN.

3.5. Examples

It seems appropriate to give some examples of the time series, and to give an idea of how they can be used. A list in readable code of a few time series straight from the magnetic tape or disk would read as in Table 2. The explanations for the different fields are given in section 3.4. It is also possible to make a less cryptic printout of the same information; this would read as in Table 3.

By combining different time series and performing some calculations, the curves shown in Fig. 4 can be obtained. These curves represent the food consumption as a daily calorie intake for certain percentages of the total world population. The broken line is the frequency distribution and the continuous line follows the cumulative distribution pattern for 1976.

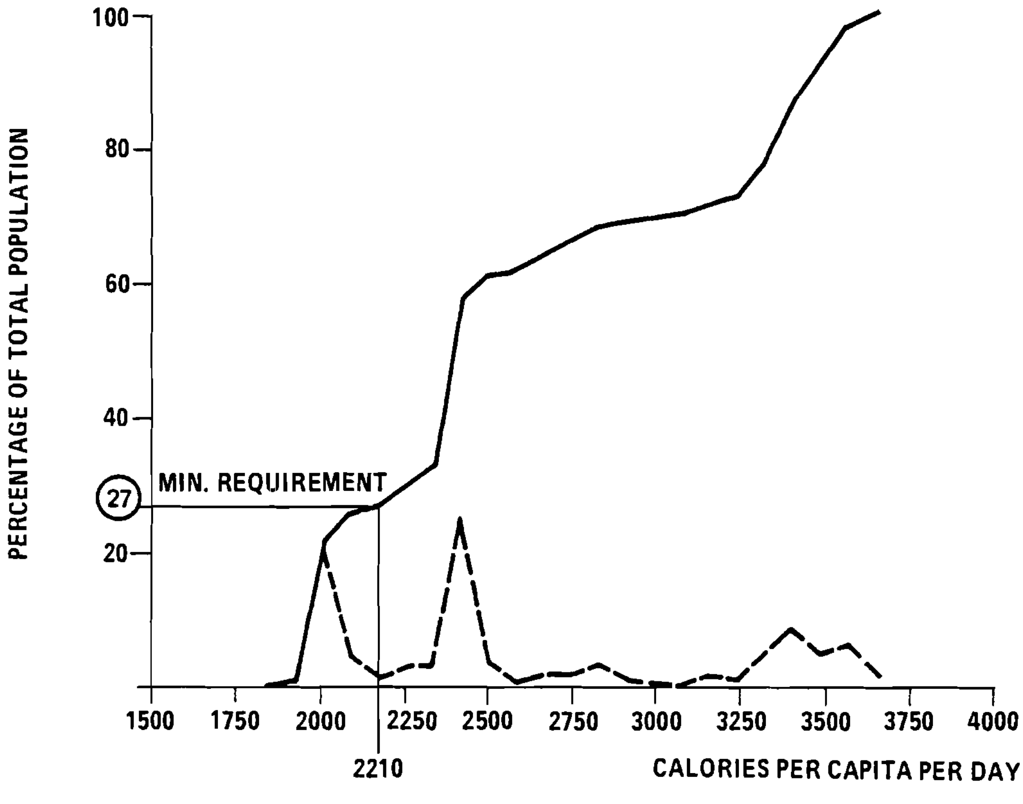

FIGURE 4 Human food intake in calories (1976).

For Fig. 5 some further computations were performed on the available time series. The y axis represents a percentage or ratio of specific countries' exports of cereals to total world exports of cereals. On ordering the world's 10 largest exporters of cereals by decreasing size, we obtain for 1976 the percentages shown in Fig. 5. It is interesting to note that the first 10 countries cover 88% of the world's total exports of cereals.

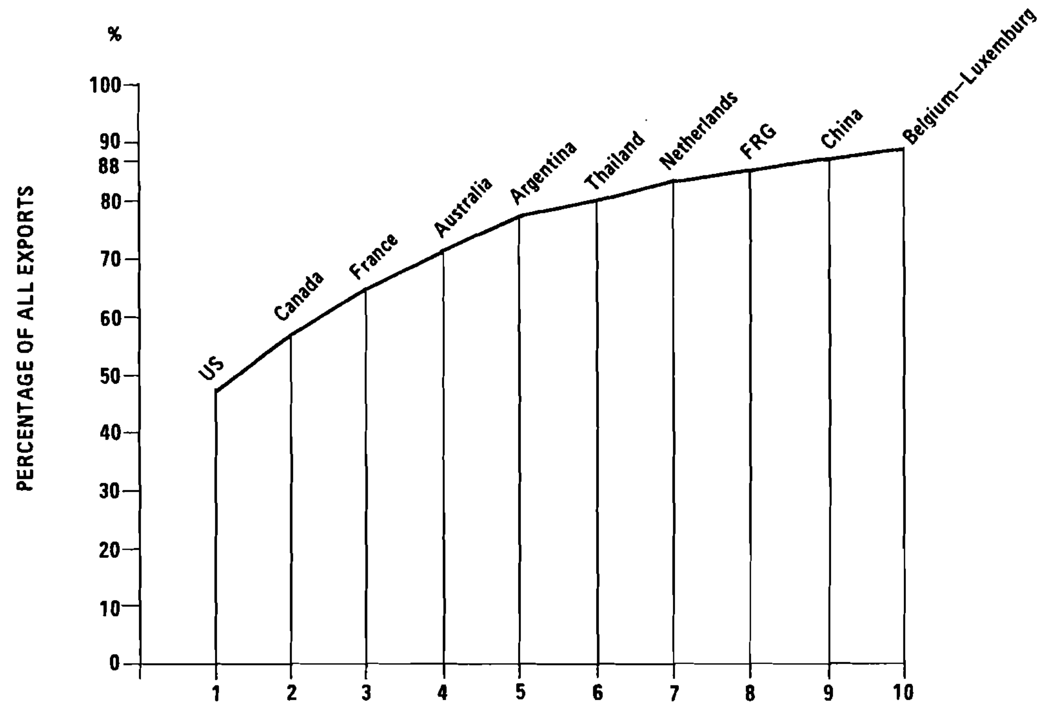

FIGURE 5 Cumulative cereal exports of the world's 10 largest exporters.

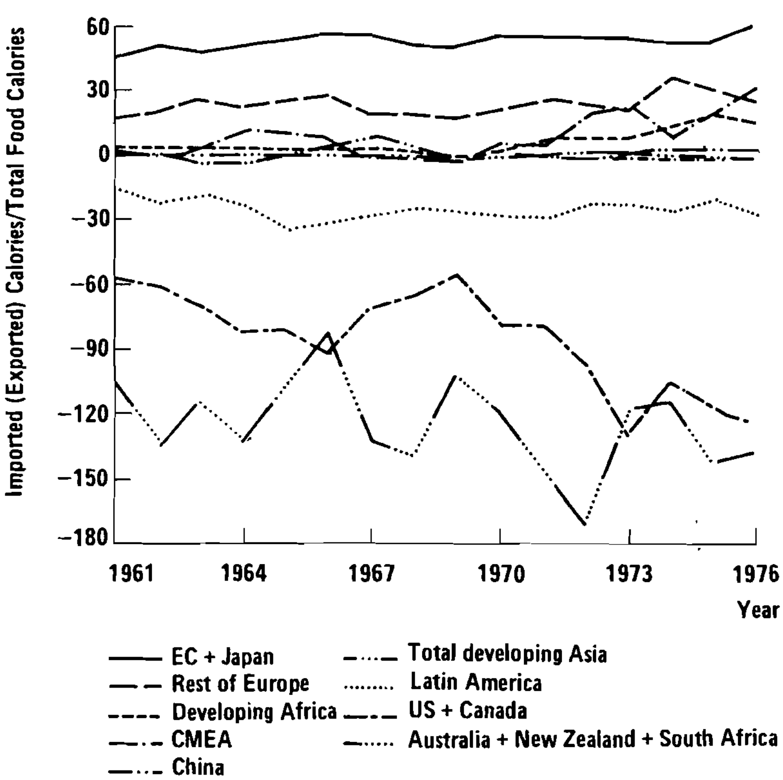

FIGURE 6 Food self-sufficiency measured as percentage of consumed calories imported (exported).

If we take a sample across time (1961 to 1976) and perform some simple arithmetic calculations, the curves in Fig. 6 are obtained.

The ratio of imported calories to total calories in human consumption gives an indication of self-sufficiency. A negative ratio denotes a net exporter (US and Canada), a positive ratio a net importer (EC and Japan). (It should be mentioned here that no account has been taken of the use of imported calories for feed purposes.)

3.6. Use of the Data Bank

The FAP data bank on agricultural commodities is certainly a useful source of information, not only for people interested in agriculture, but also for alternative energy researchers, econometricians, demographers, and others. But the most extensive use of our data bank is being made by members of the FAP and its collaborating institutions. For this user community the data bank is the input for the parameter estimations for the different equations to be used in the supply or demand sides of the models. New data also can be generated, e.g. processing margins, expenditure shares, or various types of prices. When the models have been built, calibrations and validations are also made on the basis of the FAP data bank.

The standard set of data handling mechanisms is small, because the purpose is to provide not a "universal data bank" but rather a good set of time series for the modeling work at IIASA and its collaborating institutions, thereby fulfilling specific needs.

PART 4. NATIONAL AGRICULTURAL POLICY MODELS: DESCRIPTION AND APPLICATION

4.1. NATIONAL AGRICULTURAL SECTOR MODELS FOR CENTRALLY PLANNED ECONOMIES: HUNGARY AND THE CMEA COUNTRIES

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4.1.1. Objectives and General Model Structure

We tried to develop a relatively new model structure for centrally planned food and agriculture systems using the experience gained from former agricultural modeling work in socialist countries and the results of methodological research on the general structure and linkage of national sector models. This structure:

- should incorporate the basic features of the CMEA member countries' economies
- should be suitable for incorporating the specific features of the individual CMEA countries
- should be consistent and comparable with other parts of IIASA's food and agriculture model system
- should be detailed enough to be used as an experimental tool for investigating the development of food and agriculture
- should contribute to the further development of techniques applicable in the planning and management of food and agriculture

Our main goal is not straightforward optimization, but to make a tool that offers opportunities for a better understanding of the dynamic behavior of the centrally planned agricultural systems and the interactions of their elements, so that the model can also be used for mid- and long-range projections. Unlike the normative agricultural models that have been developed, this model is descriptive in character. It reflects the present operation of the centrally planned food production systems, and the present decision making practices and economic management of the government are therefore described. At the same time, various normative elements such as government decisions and published plan targets influencing the projected operation of the system are also considered.

In the model we try to make endogenous a large part of the economic environment and the most important factors in food production. Food and agriculture is modeled as a disaggregated part of an economic system closed at the national as well as at the international level. The food consumption sphere therefore is incorporated in our model and nonfood production sectors of the economy are also represented by assuming that they produce only one aggregated commodity. Both the production of agricultural raw materials and food processing are modeled, and all products not individually represented are aggregated under "other" agricultural production and food processing

The structure of the model is outlined in Fig. 1. The overall methodology used in the model is a simulation technique. For the description of subsystems, suitable techniques, e.g. linear and nonlinear programming, or econometric methods, are employed. The model is recursive, with a one-year time increment. Subperiods within the year are not considered. The time horizon of the analysis is 15 to 20 years. Random effects of weather and animal disease conditions can also be taken into consideration.

Long-range government objectives such as the growth of the whole economy, the growth rate of food production and consumption, a given relation of consumption to accumulation, and a given positive balance of payments in food and agriculture are considered exogenously, since these are determined by the long-range development plan of the national economy.

4.1.2. A Prototype Model: the Hungarian Agricultural Model (HAM)

The Hungarian Agricultural Model has been developed as a prototype for the modeling of agriculture in the CMEA (Council for Mutual Economic Assistance) member countries. This work was a joint undertaking of IIASA and three institutions in Hungary.

HAM's structure has been developed according to the general principles summarized in section 4.1.1. Figure 2 shows the structure of the final version of the model. HAM is in fact a system of interconnected models. Two spheres are differentiated within the system: the economic management and planning submodel describes the decision making and control activities of the government; the production submodel covers the entire national economy, including the disaggregated food production sector. The major blocks of the latter submodel correspond to production, consumption and trade, as well as to the updating of available resource and model parameters. In Hungary the overall targets for food and agriculture are achieved mostly by using indirect economic means (prices, taxes, subsidies). HAM therefore represents a decentralized version of our general model structure, in which producers' decisions play quite an important role.

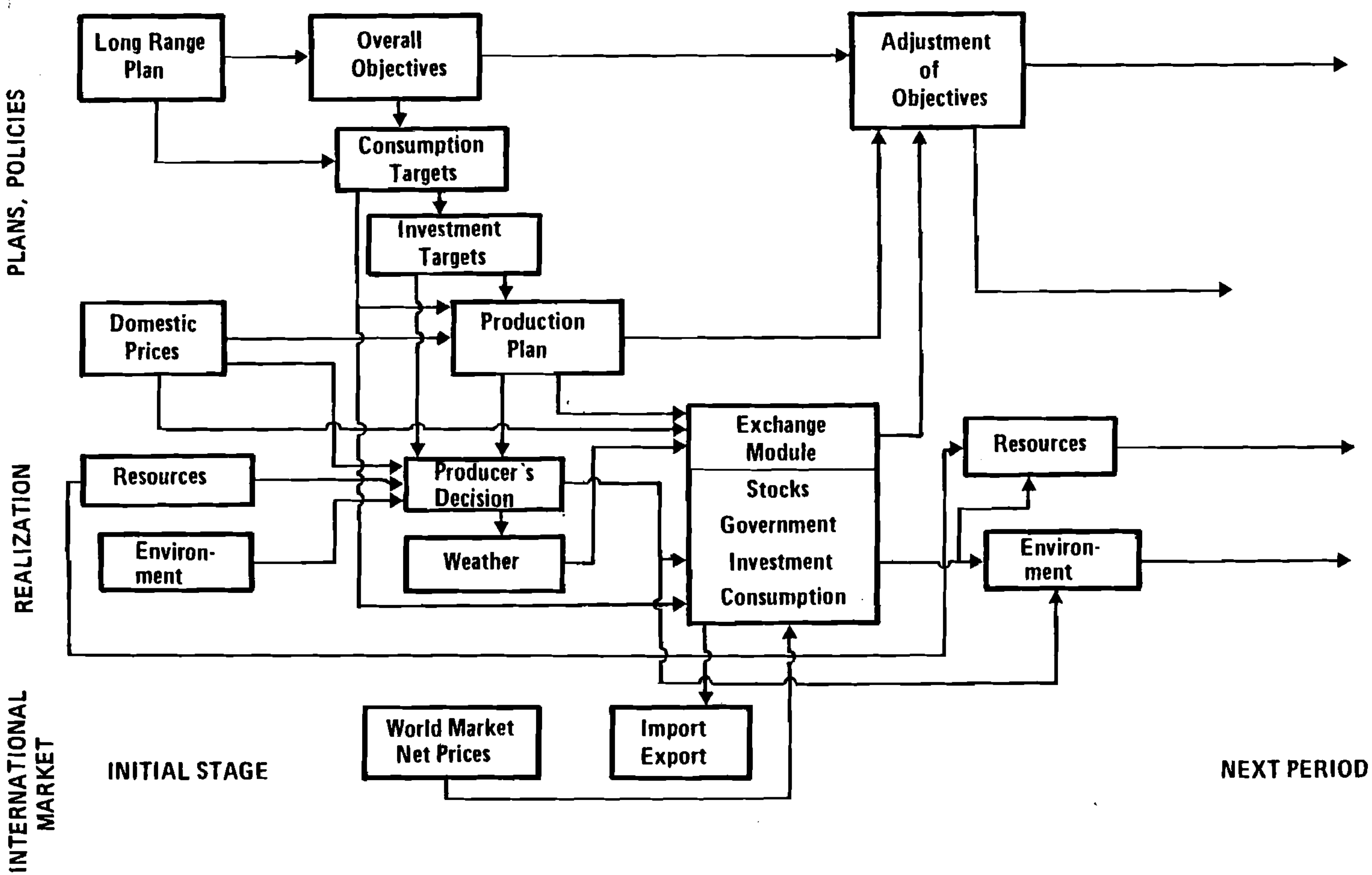

FIGURE 1 General structure of the model.

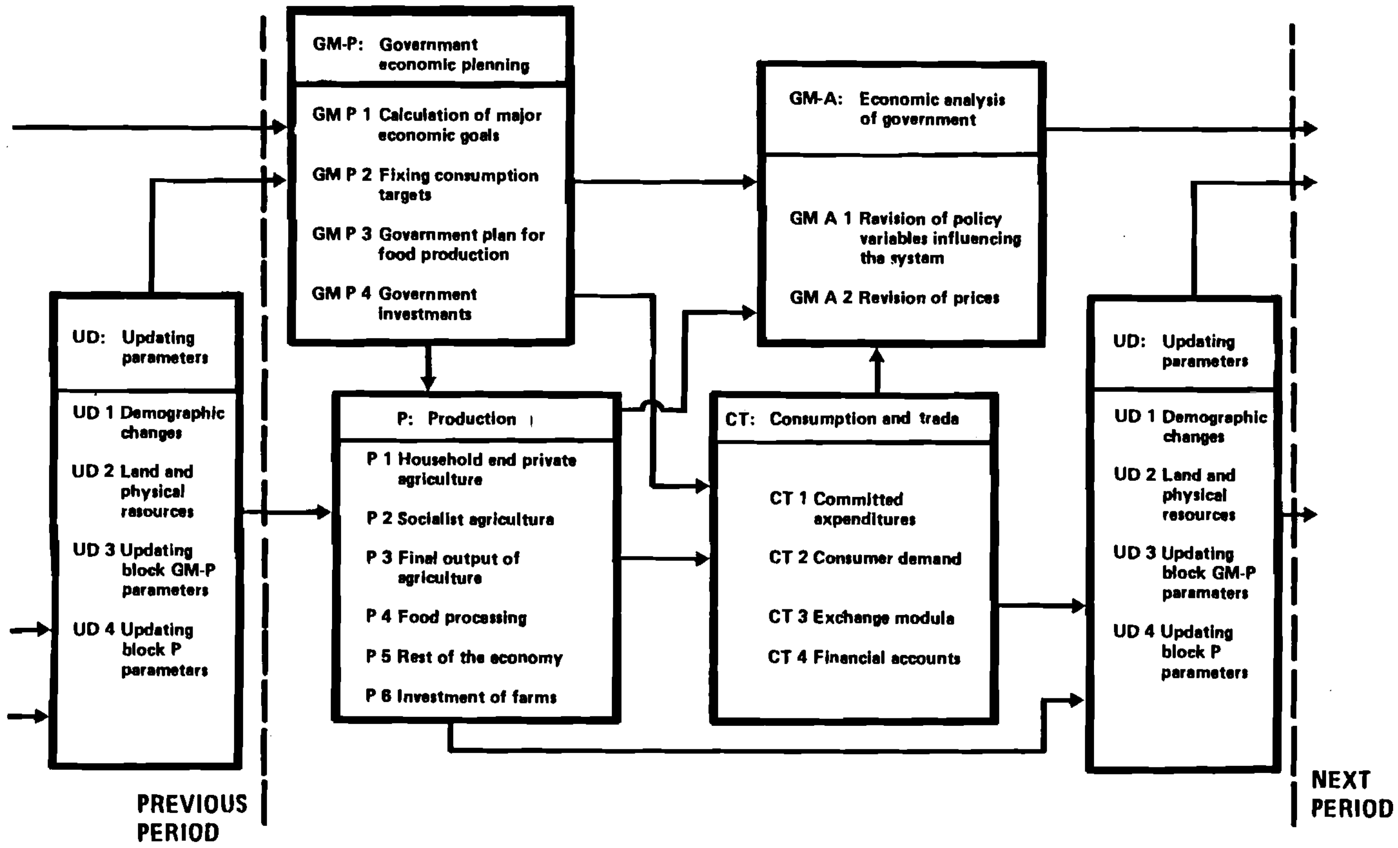

FIGURE 2 Schematic diagram of HAM.

4.1.3. HAM-1

HAM is the first system simulation model to describe the Hungarian food and agriculture sector. The earlier modeling efforts provided much useful experience, but in many ways HAM uses entirely new approaches and the development of HAM required the evaluation of several possible alternative methodological approaches. Therefore, to avoid the difficulties of immediately working with a large scale system, a more aggregated, relatively simplified model version (HAM-1) was first developed. In HAM-1 Hungarian food and agriculture is represented by five agricultural and four processed food commodities; the 10th commodity relates to the rest of the economy. Almost all the model commodities represent relatively wide ranges of products. Since the whole Hungarian food and agriculture system and the national economy are covered, the computed results of HAM-1 can be compared with the actual indicators of Hungarian food and agriculture and of the national economy.

4.1.4. HAM-2

The second version, HAM-2, completed recently, has 45 food and agriculture commodities. The detailed structure of HAM-2 can be seen in Fig. 2.

In HAM-2 the implementation of given policy objectives is made fully endogenous. Government plan targets for food and agriculture are determined by a linear programming model on the assumption that central planners want to maximize foreign exchange earnings from food and agriculture once a given level of self-sufficiency is achieved. The adjustment of overall objectives and policy instruments is modeled by heuristic routines. This is one of the first attempts at a mathematical description of the pricing mechanism in a centrally planned economy.

In the food and agriculture sector, socialist agriculture (state and cooperative farms) is modeled by a linear programming model; the behavior of private and household farms is described by supply functions and a separate model block relating to food processing. A simulation-type model is constructed to describe the investment decisions of producing firms. The output of the nonagricultural sector of the economy is calculated by a Cobb–Douglas-type function.

The exchange module is a crucial part of the whole system. As has already been mentioned, an equilibrium-type model has been constructed to obtain balance-of-trade equilibrium and to adjust to changing international market conditions. In this model stock adjustment and adjustment of government and other investments, as well as private consumption, are considered. A special version of extended linear expenditure systems has been derived to describe consumer behavior.

The parameters of the two linear programming models, the planners' decision model and the socialist agricultural model, are updated on the basis of production functions.

HAM-2 can obviously be considered as an element of the IIASA agricultural model system being developed and as such it will be linked with other national models and used for global investigations. Furthermore, HAM-2 is used in the elaboration of the next five-year plan for Hungarian food and agriculture. Several runs have already been executed to analyze the impacts of various alternatives for agricultural pricing mechanisms.

4.1.5. Some Perspectives on Hungarian Agriculture as Projected by HAM-2

During 1979–80 about 40 runs of HAM-2 were executed to answer questions relating to the mid-range development of Hungarian agriculture. The detailed discussion of the results exceeds the scope of this report and therefore only the major conclusions of the investigation are summarized.

One of the most important tasks during the calculations was to project the growth of the Hungarian national economy and agriculture. The results show that annual growth will slightly decrease over that of the 1960s, both on the national level and in food and agriculture. Under the conditions expressed by the model, it is most likely that the annual average growth rate of gross national product will be around 3%. The annual growth will probably further decrease toward the second five-year period within the time horizon modeled. Later it will increase but probably not to the level of the first five-year period. Food and agriculture grows in parallel with the rest of the economy in most of the runs. As far as growth rates are considered in various scenarios, substantial differences can be observed in the second half of the period modeled.

Several exogenously given scenarios on international prices and world market conditions have been tested. The results indicate the following.

- Stable international market conditions favor the achievement of growth targets
- The reaction of the Hungarian economy, including food and agriculture, to world market changes is slow
- Changes in food export quotas do not significantly influence the overall quota figure
- The transfer of international market changes to producers is not efficient enough: producers have no direct contact with world markets and their actions may therefore have undesired results
- As was expected, exchange rate controls did not prove to be efficient instruments for controlling overall growth

Government policy objectives for the growth of private consumption have a substantial impact on overall economic growth. Overall economic growth is most favorable for an annual growth in consumption of only 2%. An annual growth of more than 3.5% in consumption leads to a substantial slowdown in overall economic development. On the other hand, too slow an increase in consumption also has negative effects on production. An annual growth in private consumption of 2.5–3.0% therefore seems to be the most realistic target for the next 15 years.

Investigations of the impacts of various government pricing policies confirmed our expectations: prices and price policy are the most effective tools in the hands of the government for controlling producers' behavior within the framework of conditions expressed by HAM.

The desired relation of consumption and investment has also been studied. As has already been mentioned, from the point of view of the economic growth of the country, an annual growth in private consumption of 2.5–3% is the most desirable. According to the results of various runs, the given state of the economy very seriously limits the possibilities for increased consumption. Obviously a larger share of consumption in total national income leads to less investment. An annual growth in consumption of more than 2.7–2.8% seems to be realistic only in those scenarios where very favorable international market conditions are assumed. A higher growth in consumption leads to a decrease in investment and overall economic growth falls below the desired level. An almost general conclusion of our calculations is that a slowly increasing share of investment in national income would be most desirable in the future, and therefore that the growth of investment must be higher than that of consumption.

Food and agriculture meets the consumers' demands in almost all cases considered, and there is a substantial supply also for export. The objective of 100% self-sufficiency in commodities that can be produced in Hungary seems to be realistic.

The share of food and agriculture in total accumulation varies greatly in different scenarios. In general, agriculture is able to accumulate the funds necessary for its own development, and government subsidies are used only in specific cases. However, in food processing the government subsidies are the major financial source for development. It is surprising that most of our runs reflect a relatively acceptable level of incomes in agriculture. Firms in food processing, partly owing to the age of the present production facilities, are not able to accumulate enough money to finance the investments desired at the domestic price level projected by HAM.

One of the major objectives of the investigation was connected with the export potential of Hungarian food and agriculture. The results indicate two important conclusions.

- The export potential of Hungarian agriculture has so far not been fully realized; the positive balance of foreign trade in food and agriculture can be significantly increased.
- The quantity of exports could be increased, but the efficiency of exporting food above a certain limit is questionable

The various scenarios led to different production structures in food and agriculture. On the whole, though, they do not indicate the necessity for a substantial change in the present production structure. However, they indicate the need for consideration of the following changes:

- increasing the role of grain production (wheat and corn) and of oil seeds within crop production
- increasing the number of orchards and especially increasing the number of vineyards for quality wine production
- increasing the share of processed and especially highly processed commodities in total exports

4.1.6. Model for the CMEA Agriculture Sector

Based on the experience gained in developing the Hungarian Agricultural Model, an aggregated CMEA model has also been constructed at IIASA. The CMEA model is designed primarily to represent the European centrally planned economies within IIASA's aggregated model system, with the main objective of developing a model that realistically describes the aggregated behavior of this group of countries in the international market for agricultural commodities. The model is not for detailed study of the problems of agricultural development of the CMEA countries. However, we hope that by virtue of its aggregated character it will be useful for investigations of these countries' overall problems of agricultural development. The following issues can be investigated on the basis of the model:

(1) the main alternatives for the realization of major targets on growth of agricultural production
(2) the key factors and conditions of realization
(3) the interaction of agricultural and industrial development
(4) more or less investment in agriculture
(5) the feasibility of certain overall targets
(6) consumption versus investment

The CMEA model, which actually covers the European CMEA member countries (Bulgaria, Czechoslovakia, the GDR, Hungary, Poland, Romania, and the USSR), has a structure consistent with other elements of the aggregated model system, including the same commodity coverage. Figure 3 shows the general structure of the model.

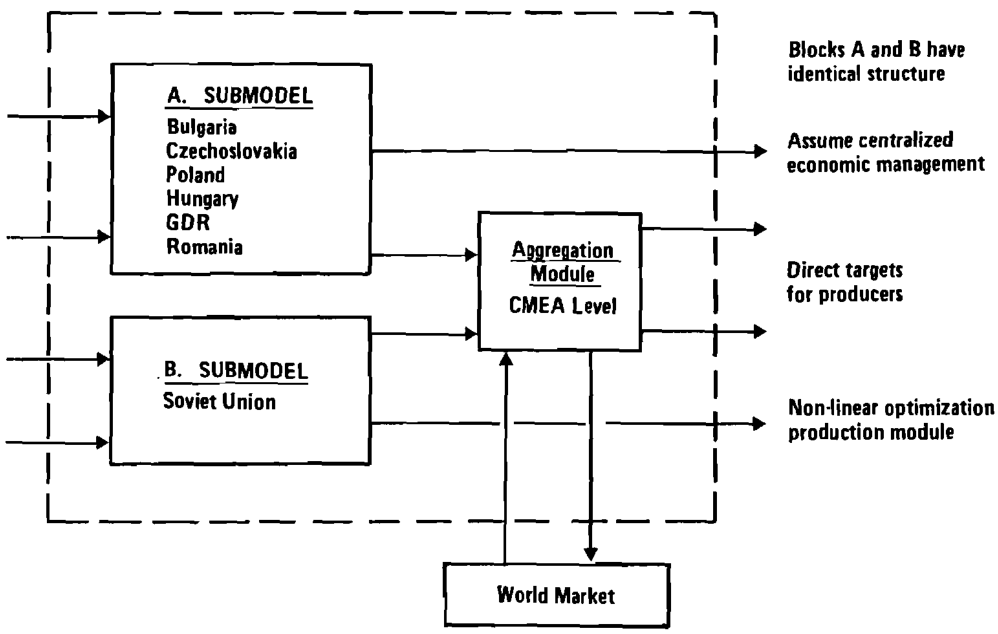

FIGURE 3 The structure of the CMEA model.

In the model it is assumed that the most important long-range government policy objectives, such as the required growth rate of the overall economy and of private consumption, as well as the share of agriculture in total investment, are fixed according to actual data from CMEA countries. Production is modeled by a nonlinear optimization model, consumption and trade are described by a special equilibrium model, and government objectives are adjusted using heuristic routines. The production list of the model conforms to the commodity coverage of AT 2000 (FAO, 1979), but some commodities are aggregated (food and agricultural commodities in the model are wheat, rice, coarse grains, sugar, vegetables, bananas, citrus fruits, other fruits, vegetable oils, cacao, coffee, tea, cotton, other nonfood products, rubber, other feeds, beef and veal, mutton and lamb, pork, poultry meat, dairy products and eggs). The model and its parameters are structured in accordance with the Soviet Union and the smaller CMEA countries, and in its application is run as two submodels which have identical structures as outlined above. The model uses FAO population and demand projections, and is fundamentally based on data available from the FAO.

4.1.7. The Scenarios and Results

Basic scenarios computed by the CMEA model were determined according to the major assumptions of the FAO's Agriculture: Toward 2000 Program. Similarly to other developed countries within the AT 2000 Program, we assume moderate rates of economic growth according to the AT 2000 Normative Medium Scenario. On this assumption, two basic scenarios were calculated by the model: the Constant Self-Sufficiency Ratio (SSR) Scenario, where SSRs of 1975 are made minimum requirements in production modules, and the so-called Normative Medium Scenario, where most of the restrictions on SSRs are dropped. To help to delimit the spectrum of production possibilities in the two basic scenarios, several other model versions have been computed, mainly by running the Soviet Union and Eastern Europe submodels separately. The major questions of these investigations were related to the effect of migration from agriculture, various levels of investment in agriculture, different balances of payments, changes in feeding efficiency, etc.

Two basic scenarios and related calculations give reliable information on the possible lower and upper limits of production. First of all, it is necessary to point out that the course of agricultural development in CMEA countries will largely depend on the national situations. Efforts to satisfy growing consumer food demands and to maintain or increase the level of self-sufficiency can be considered the main driving forces of future development. Of course, changes in international market conditions might also have some influence. High prices on the world market might represent an additional reason for developing agriculture to save foreign exchange in the importing countries and to utilize export potential in a period of surplus. Low international prices first influence exporting countries, which in this situation might restrain agricultural development and invest more in other areas. However, the CMEA countries' reactions to world market changes will be much more moderate and slower than those of other developed countries. The results of the two basic scenarios can be seen in Tables 1 and 2.

Our two basic scenarios are very similar as far as the projected overall growth of agricultural production is concerned. In contrast to the relatively moderate growth of the economy as a whole, a substantial growth of agricultural production can be projected (2–3% annually). It can be expected that growth of production will be greater than that of

TABLE 1 Agricultural output and SSRs of CMEA countries — Constant SSR Scenario.

	1975		2000	
	Total Output	SSR	Total Output	SSR
Total cereals (1000 m.t.)	254369	0.93	437650	0.99
Wheat	108868	0.93	166508	1.00
Rice	2135	0.75	5182	0.80
Coarse grain	143366	0.92	265959	0.99
Total meat	22945	1.11	37505	1.32
Beef and veal	8551	0.99	14744	1.32
Mutton and lamb	1159	1.02	1991	1.43
Pork	10564	1.25	15816	1.42
Poultry meat	2671	1.07	5042	1.04
Milk and milk prod.	129507	1.00	221520	1.14
All agr. comm. (mill. US $)	138890	1.00	230409	1.11
Total volume of agr. trade (mill. US $)	7491	5.4	23196	10.1

TABLE 2 Agricultural output and SSRs of CMEA countries — Normative Medium Scenario.

	1975		2000	
	Total Output	SSR	Total Output	SSR
Total cereals (1000 m.t.)	254369	0.93	420710	0.93
Wheat	108868	0.93	158439	0.94
Rice	2135	0.75	955	0.15
Coarse grain	143366	0.92	261316	0.94
Total meat	22945	1.11	39998	1.40
Beef and veal	8551	0.99	15581	1.39
Mutton and lamb	1159	1.02	2097	1.17
Pork	10564	1.25	17024	1.52
Poultry meat	2671	1.07	5295	1.09
Milk and milk prod.	129507	1.00	223507	1.17
All agr. comm. (mill. US $)	138890	1.00	232410	1.10
Total volume of agr. trade (mill. US $)	7491	5.4	41592	17.9

domestic demand, in parallel with the increase in the SSRs for the most important agricultural commodities. This development reflects the fact that very substantial production reserves exist in the area, especially in the Soviet Union. In our opinion, the significant investment allocated for agriculture in recent years will bear fruit in the forthcoming period, and a moderate food surplus can even be forecast in the region by the end of the century. Domestic food demands are forecast in our scenarios in accordance with FAO projections. On the whole, for the CMEA region we expect a relatively moderate growth of both domestic food demand and consumption. In total calorie consumption, each CMEA country has already reached the level of 3000 calories per person daily. A further increase in this level does not seem desirable, but the structure of consumption will change. During the forthcoming period the structural change in food consumption will be determined by fast-growing consumer demand for meat and meat products, as well as fruit and vegetables.

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4.2. THE EUROPEAN COMMUNITY AGRICULTURAL MODEL

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4.2.1. General Structure of the Model

Given that the European Community (EC) is the largest importer of agricultural products in the world, and at the same time the second largest agricultural exporter, developments on EC markets as well as decisions taken by EC policy makers have a significant effect on international relations in agriculture. Work on a model for the EC was accordingly started by the FAP at an early stage.

Apart from sheer size considerations, the EC has a significant impact on international agricultural trade because it pursues a rather protectionist policy. Domestic prices are kept considerably above world market prices and, in addition, domestic markets are shielded against international fluctuations by a specific set of stabilizing policies. The main objective of these policies is to assure farmers acceptable and stable incomes. The external effects of these policies are important issues to be analyzed.

Work on the EC model has been carried out through cooperation between the FAP at IIASA and the Institute of Agricultural Economics of the University of Göttingen in the Federal Republic of Germany. The latter received a grant from the Volkswagen Foundation that helped to finance the research done at Göttingen.

The nine member countries of the EC are modeled individually, and each of them is dealt with as one homogeneous aggregate. Parameters are estimated econometrically as far as is possible.

Much emphasis is placed on modeling the relationship between factor input into agriculture and agricultural output. In terms of the recursive model structure, first input levels in agriculture (land, labor, machinery and buildings, capital, fertilizer) are determined. Output of individual commodities is then derived from a supply component in which inputs are allocated to production activities. Demand is modeled in a demand component on the basis of prices and incomes. Prices are influenced by agricultural policy measures which are determined endogenously in an agricultural policy component.

4.2.2. Agricultural Policy Component

The close interrelationship between agricultural price policy and the economic situation of the farming industry
in the Community was considered to require endogenous modeling of

agricultural policy decisions. The agricultural policy component is thought to represent the annual price-fixing decisions of the Council of Ministers in Brussels. In principle these are decisions on a common level of support prices for all member countries. A certain device ("green currencies") to even out exchange rate fluctuations between member countries has, however, provided some scope for national price differentiation. It is therefore possible to base parameter estimation on a pool of cross-section and time series data.

Although it would be preferable to work with a truly structural model containing the policy makers' objective functions and decision algorithms, as well as describing (for example with the aid of a game theory approach) the negotiations between the ministers of member countries, the current approach is to estimate policy response functions which relate support prices of individual commodities to a set of explanatory variables such as rate of inflation, farm income level, and budget burden of price support.

4.2.3. Demand Component

The demand component is specified as a dynamic linear expenditure system. The dynamic element assumes the form of habit formation, which means that committed demand depends on the previous year's consumption.

Basic data on which parameters are estimated are time series of aggregate consumer expenditure by commodity group and country. As information on the consumption of individual commodities within commodity groups stems from other sources, demand is split up into individual items at a lower level of the demand system. This means that the overall demand system is of a hierarchical nature. At the lowest level (currently the third level) individual agricultural raw materials according to the IIASA/FAP commodity list, and processing and distribution, which are taken as part of the nonagricultural good, are distinguished.

4.2.4. Supply Component

Supplies of agricultural products and of the nonagricultural aggregate are determined in two different modules.

4.2.4.1. Supply of agricultural commodities

It is hypothesized that the numerous decisions farmers make during a year to determine output can be reduced to only two decision stages. In the first stage farmers are assumed to decide on the level of input of such factors as labor, buildings and machinery, and land. This is followed by a decision on the allocation of these inputs and nonpredetermined factors (fertilizer, feed), and thereby farmers determine the output of the various commodities.

For modeling the inputs of labor, buildings and capital, a cost minimization component is set up. According to this component, farmers minimize the cost of (aggregate) production with regard to labor and capital given planned total output and an aggregate production function. The first-order conditions, which are solved for labor, buildings and machinery, are econometrically estimated. While the resulting input of labor is considered as actually being used, that of buildings and machinery is interpreted as describing the "desired" stock of these two capital items.

The "desired" capital stocks, together with the previous year's actual capital stocks and liquidity variables, are further used in investment functions which describe the investment behavior of farmers in relation to buildings and machinery. Given gross investments, actual capital stocks of the two items are then determined by using the perpetual inventory method. It is assumed that the average life of a machine is 10 years and of a building is 50 years.

In the second decision stage farmers allocate the various inputs to a set of commodities. Various methods of modeling such a multiple input, multiple output system are known from the literature. They are summarized by the first three items in the first column of Table 1. Their basic characteristics are highlighted in columns 2 to 4. However, none of them is followed here. Instead, we use the nonlinear programming approach indicated in the last row of Table 1. Most of the parameters of this programming model are econometrically estimated by using time series information from 1961 to 1976. Those parameters which are not based on statistical data are derived from engineering information.

TABLE 1 Modeling multiple input, multiple output systems.

Model type	Explicit assumption about criteria for decision making	Explicit consideration of production structure	Parameter hypothesis testability
(1) Mathematical programming with linear production structure	Yes	Yes	No
(2) Direct supply functions	No	No	Yes
(3) Dual approach	Yes	Yes, with some limitations	Yes
(4) Mathematical programming with nonlinear production structure	Yes	Yes	Yes

We hypothesize that farmers maximize expected gross revenue, minus the costs of feed and other nonpredetermined inputs, given the yield functions for crops and the mechanization functions. Crop yields are functions of fertilizer measured as pure nitrogen applied per unit of land and of the share of total acreage allocated to the corresponding crop. The latter term is a proxy for the increased hazard from plant diseases and for the decline in the suitability of soils as the acreage share is enlarged. The mechanization function determines the acreage allocated to each crop and the numbers of each animal type husbanded according to the bundle of labor and capital used for the respective commodity. Biological–technical progress is incorporated into the yield functions in the form of a trend variable. The mechanization functions measure embodied technical progress.

The programming model contains a set of linear and nonlinear constraints which assure that the amounts of the various predetermined inputs allocated do not exceed their total availability.

The feed requirement coefficients in the model are annually updated. The updating functions used are first-order conditions derived from a feed-cost minimization model that describes the optimal feed mix input. These functions (having feed-price ratios as determining variables) are estimated using time series data on feed consumption.

The agricultural supply component is validated using criteria such as goodness of fit, t statistics of the estimated parameters, ex post forecasting capability, plausibility of the estimated allocation and estimated shadow prices of the predetermined inputs, and the resulting long-run supply elasticities. Table 2 depicts the long-term direct supply elasticities we have obtained so far for the Federal Republic of Germany. They are based on a 15-year adjustment period.

TABLE 2 Long-run direct price elasticities of supply for the Federal Republic of Germany.

Commodity aggregate	Elasticity
Wheat	0.853
Coarse grain	0.551
Oil fruits, protein feeds, industrial crops	1.530
Fruit and vegetables	0.334
Pork, poultry and eggs	2.226
Bovine and ovine meat	0.942
Milk	1.224
Wool	0.058

It should be mentioned that the rather low elasticity of the aggregate fruit and vegetables may be due to the policies used to regulate the supply of fruit. The government of the FRG often utilized other instruments in addition to price policies to bring supply into line with demand; for example, sometimes it paid premiums to enlarge the acreage of orchards and occasionally it subsidized the clearing of them. The price response of this commodity aggregate might therefore be lower than expected.

4.2.4.2. Supply of the nonagricultural commodity

Supply of the nonagricultural commodity is modeled as a Cobb–Douglas production function. The quantities of labor and investment used in the nonagricultural sector are obtained as the difference between their availability to the whole economy and that amount engaged in agricultural production. Investment is converted into capital stock by using the perpetual inventory method, as briefly described for the agricultural supply component.

4.2.5. Status of the Work

At present, work on the demand system is nearly completed for all member countries. The allocation model has been estimated for the FRG, and preliminary results for France and the Netherlands have also been obtained. A first version of the input factor model has been estimated for all member countries. It is hoped that the policy component will be finished by the end of 1981. Work on the EC modeling, made possible by a grant from the government of the Netherlands, will continue over the next three years.

4.3. RESOURCE AND INFRASTRUCTURE CONSTRAINTS AFFECTING THE GROWTH OF CANADIAN AGRICULTURE

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IIASA and Agriculture Canada are cooperating on the development of a Canadian agricultural model within the IIASA world food modeling system. This effort commenced only about six months ago, and we are thus unable to report on results from a detailed Canadian model. We shall report on our experiences with the simplified national model of Canada developed at IIASA by Fischer and Frohberg (1980) and elaborate the current direction of our research efforts.

There are obvious advantages in participating in the IIASA modeling exercise. Access to the methodological expertise at IIASA and the linking of the Canadian model with other national models in an international trade setting are important. At the same time we have been able to introduce some specific information about Canadian institutions and about research issues all guided by a programmatic concern to develop a functioning model that is capable of shedding light on pressing policy issues.

4.3.1. Current Canadian Agricultural Policy Issues

There is increasing evidence that Canadian agriculture is entering an era of much higher growth in the demand for agricultural products, largely led by the export sector. This scenario is based on different international studies. The UN Food and Agriculture Organization's Agriculture: Toward 2000 study concludes that for the next two decades agriculture in developing countries is going to have to grow at twice the rate it did during the period 1963–75. In the Global 2000 Report to the President of the US, a rather pessimistic conclusion about the world's ability to meet food requirements is presented. It concludes that the growth of food supply will be limited because little new land exists, that a degradation of natural resources is occurring, that native genetic strains are being lost, that more energy-intensive inputs are required for newer food-producing technologies and that there is an increasing sensitivity of new food-producing areas to the vagaries of weather. At the same time, world food demand, particularly in the developing countries, is rapidly growing. Given the relatively inelastic nature of food supply and demand, prices are expected to increase rapidly in real terms, by as much as 100% by the year 2000. Canada has traditionally exported substantial parts of its grain and oilseed production and to a lesser extent its livestock. Agricultural exports are the equivalent of about 40% of farm cash receipts, and Canada has benefited from a substantial devaluation of its currency during the period 1973–79 – by 18% against its major competitor, the United States, but by over 60% against the Deutschmark and the Japanese yen. This devaluation has been important for the freely traded livestock grain commodities. In addition to these factors that influence the commercial market, the Canadian government has indicated that it is likely to expand its food aid commitments, so the demand growth for Canadian agricultural products appears strong.

Following this scenario a new policy thrust is emerging for Canadian agriculture. Past policies were aimed at tackling such problems as declining terms of trade, excess production, excess resources, and a number of equity considerations. To capitalize on this growing demand for agricultural products, Canadian policy makers are currently faced with the task of directing policies that will upgrade the natural resource base and improve the infrastructure, thereby accelerating agricultural development. A series of policy initiatives has been taken, aimed at resolving these constraints: a Western agricultural development strategy, plans to improve the grain-handling and transportation system, and a renewed biological research thrust. Some of the priorities concerning upgrading the resource base include, for example, incentives to bring new land into production, improvements to existing land, changes in tenure and zoning regulations, a reduction in the area of prairie summerfallow, as well as increased irrigation, drainage and snow control, and the prevention of further soil degradation through salinization, compaction, and erosion. Research and development efforts are concentrating on yield-increasing, energy-reducing projects and on providing varieties for northern development. The most pressing infrastructure improvements relate to grain-handling and transportation improvements, which require a doubling of the throughput for export in the next five years. Stabilization programs will also remain an important element of agricultural policy, reducing the effects of short-term cycles, but these programs will also try to prevent undesirable side-effects such as maintaining resources in declining-growth products, unnecessary restrictions on output and reductions in efficiency.

Turning to some policy applications where the IIASA model may be useful, a model for Canadian agriculture must be able to examine alternatives aimed at increasing the growth and efficiency of agriculture while also considering the returns to resources in agriculture. It should also be capable of allowing for an examination of policies directed toward market development, stabilization, factor inputs and infrastructure, structural change, research and development and regional advantages and disadvantages. To be more specific, let us consider the grains exports sector. A target has been established for the export of grains and oilseeds in 1985 of 30 million tonnes. This is a 38% increase over the 1980 record of 21.7 million tonnes. The IIASA model might be used to examine a number of aspects of the marketing system involved with this export target – the production side, the marketing and transportation side and the inventory-holding and sales behavior of the Canadian Wheat Board. On the production side, additional grain production can be obtained either through expanded acreage from new lands or reduced summerfallow (about 25 million acres), or through higher yields from purchased inputs (currently at very low levels), or through better management and genetic improvements. The new lower grades of wheat offer a much greater potential for expansion in yields than the traditional varieties. Marketing and transportation capacity has traditionally been restricted because of a number of factors: the rail line capacity, particularly through the Rocky Mountains, the number of railroad cars available and their efficiency of use, the port elevator throughput and labor disruptions. The government is pursuing a number of policies related to all these areas, with the hope of expanding the capacity over the next few years. In addition to these physical constraints, the Canadian Wheat Board pursues a discretionary stock-holding policy for speculative purposes, to fulfill contractual commitments and perhaps for other reasons such as to avoid losses on initial payments to producers. The Wheat Board sales policy has tended to concentrate on traditional markets and on high quality wheats. Neither of these markets has had one of the highest growth rates, so that a switch to lower grade wheat and an expansion of sales to developing countries may be the only way of reaching the export target established.

The simplified system may be used in various ways to assess these policies over the period 1980 to 2000. On the production side, we could look at the feasibility of production expansion through the incentives required to bring more land into production, either from summerfallow or by adding new land, or to use more inputs, or to look at the impact through technological and management improvements. On the marketing and transportation capacity, one could look at the various levels of capacity for each of the years from 1980 through to 2000. On the sales stockholding strategy, we might examine whether the Wheat Board would sell a higher percentage of available stocks and the impact of reducing marketing constraints. The model allows an evaluation of the feasibility and the direct implications of these changes and it also provides an assessment of these changes in the livestock sector and of such macrovariables as farm income, food prices, input usage and so forth.

There are many other policy issues that may be mentioned as they relate to an IIASA simplified or condensed model. Instead we briefly report on some results obtained from the Canadian basic linked model and detail our current research strategy.

4.3.2. The Basic Linked Canadian Model

In starting to piece together a Canadian agricultural supply module, it is naturally useful to review what has already been done. Within Agriculture Canada the history of model development may be divided into three time periods. Prior to 1972 there was virtually no quantitative economic model. The period 1972 to 1977 saw a rapid implementation of a variety of quantitative model approaches. Since 1977 the main thrust has been a concentration on commodity-specific quarterly econometric forecasting models (Huff, 1980). Various starts on general equilibrium models have been made in Agriculture Canada and in the universities, but there currently exists no model suitable for linkage with the FAP model system. The present research effort attempts to fill this gap.

It was considered that a useful start could be made by examining the simplified Canadian model developed by Fischer and Frohberg (1980). The methodology adopted by them is new. The same methodology is being used by Frohberg for all the EC countries, and from a practical point of view any improvements made in the model may also lead to changes in other country models represented in the basic linked system.

It is also believed that from an operational point of view a system of basic linked models can be maintained and updated at IIASA, and consequently these models are a critical component of the overall research strategy of the FAP. It was therefore considered useful to see whether the Canadian model could be developed along similar lines.

In this attempt at evaluation, results for a historical period were examined, a 10-year forecast for the period 1980 to 1990 was provided, and various simulation experiments were made (Graham and Huff, 1980; Rabár and Huff, 1980). The tests may be summarized by reporting that the model performs reasonably well over the forecast period. Table 1 illustrates one such set of results. Model forecasts of wheat output are compared with other official forecasts mainly over the ex ante period.

TABLE 1 A comparison of actual versus estimated wheat production for Canada (in million tonnes).

Year	Actual wheat production	Estimated wheat production	
		MSED* estimates	Model results
1975	17.1		18.7
1976	23.6		18.6
1977	19.8		19.1
1978	21.1		20.0
1979	17.5		19.8
1980		18.8	19.5
1981		19.4	19.7
1982		20.0	19.9
1983		20.6	20.3
1989			21.4

*Offical forecast by the Canadian Ministry of State for Economic Development.

The model did not track the beef livestock cycle well because delayed responses to price fluctuations are not adequately treated. In addition, in these models, beef and dairy production are treated as an aggregate. The coefficients of the various production functions estimated need to be validated and it was also considered that country-specific policy components should be added. In spite of these few drawbacks, the simplified model offered a valuable analytical tool from which useful information may be derived. It should be noted that this model was developed with limited resources, together with many other simplified models. Given that some country-specific information is included in the conceptualization of the model, the methodological approach appears promising. It has been decided to follow this approach in the detailed Canadian model, which would form part of the FAP linked system of detailed national models, but we are also estimating a standard econometric supply model and will at a later stage decide which is most suitable.

4.3.3. Current Research Directions

The task of developing a detailed national model may conveniently be grouped into four major tasks:

- the agricultural supply module
- the demand module
- the nonagricultural/macro module
- a link-up with the international trade framework once these modules have been validated

The research strategy adopted is to develop an initial working model and then to make improvements to certain sectors as resources permit. Both the agricultural supply and the demand modules have been estimated. Work on the other two components is still to follow.

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4.4. US MODELS IN THE IIASA/FAP GLOBAL SYSTEM

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4.4.1. Introduction

The 1970s witnessed a remarkable shift in the major influences driving the United States' agricultural sector. The world experienced sequences of droughts, floods, bumper crops and famines which, coupled with the entry of major new importers into world grain markets and expanding populations in developing countries, introduced unprecedented instabilities into world markets. At the same time, by economic and political tradition, US participation in these markets is primarily through the private sector, with minimal government involvement. Thus, US farmers and food consumers are more closely integrated with, and hence subject to the vagaries of, these increasingly unstable world markets than any other major food and feed exporter – perhaps more than most other countries, whether importers or exporters.

From this point of view, therefore, it is essential that analysis supporting US food and agriculture policy capture this national–international interdependence. This observation holds for both domestic and trade-oriented policy, since the two are becoming increasingly indistinguishable.

Michigan State University* and IIASA's Food and Agriculture Program have therefore been collaborating in the development of the US intermediate model for linkage in the FAP's global system. Recently, this collaboration has been expanded to include the participation of the US Department of Agriculture** in development of the detailed US model. The status and plans for each of these models are summarized in this report.

4.4.2. The Intermediate US Model: Description and Preliminary Application

A brief overview of the intermediate model and preliminary experiences applying it to illustrative policy analyses are presented in this section. More detailed descriptions of the model can be found elsewhere (Mitchell and Christensen, 1981; Abkin, 1980). Crop production is projected on the basis of acreage and yield equations which are functions of

* Through its Department of Agricultural Economics and the Michigan Agricultural Experiment Station.
** Through Cooperative Agreement No. 58-3J22-0-00245 between the US Department of Agriculture and Michigan State University.

lagged crop prices, government policies and input prices. Government policies explicitly considered include various kinds of support prices (e.g. loan rates, target prices) and acreage restrictions (i.e. set-asides and voluntary diversions). Adjustments of these policies over time in response to simulated conditions – such as stock disappearance ratios and cost-of-production growth rates – are endogenously determined (Waites, 1980). Livestock production, in a similar vein, is determined generally as the product of number of animals slaughtered and yield per animal. Livestock numbers are determined by biological as well as economic relationships, and yields depend on livestock prices, feed prices, and trends.

On the demand side, consumption of feed grains and of high protein feeds is projected as the product, again, of animal numbers and feed consumed per animal, the latter depending primarily on relative prices. Per capita human consumption of each commodity is an asymptotic function of own and cross prices and income, subject to an overall budget constraint. There are also equations which project disappearance (seed and loss), industrial consumption, and government consumption for each commodity.

Stock demand functions are estimated for soy beans, peanuts and milk. For wheat and coarse grains, synthetic functions are used to represent the policy stock behavior of building stocks to support the loan rate and selling stocks as prices rise, where stock levels are at a minimum above the "call" price.

Finally, price relationships translate equilibrium retail-level prices at the 10-commodity level of the FAP's simplified system to retail and producer prices at the 20- and 25-commodity levels of demand and supply, respectively, in the US intermediate model.

The US intermediate model was tested with nine other country models in the FAP's basic linked system in the context of two policy scenarios. One scenario assumed a ten-fold increase in the use of corn for gasohol production in the US from 1980 to 1995; the other assumed that the EC would remove meat import tariffs, essentially substituting meat imports for feed grain and protein feed imports.

Space does not permit the presentation here of specific results of these test scenarios; however, some general observations can be made.

(1) General responses to the scenarios were in the expected direction, but the magnitudes were substantially lower than expected.

(2) The "rest of the world" was relatively large in these tests, and, since the basic linked system's current rest-of-the-world model tends to have very high trade elasticities, imports in the scenarios were almost totally absorbed by the rest of the world, world prices and the ten countries linked remaining relatively little affected.

(3) The dependence of the realism of the system's behavior on the realism of each individual country model was strongly confirmed.

That these tests did not produce results good enough to provide serious policy direction is not a problem, because that was not the intention. Rather, the important conclusion to be drawn from these experiences is that the system works well enough to allow serious and extensive testing and the identification and subsequent correction of weaknesses. It is only through such continuous testing and improvement, that this or any other model gains the degree of credibility necessary for use in policy analysis.

4.4.3. The Detailed US Model: Progress and Plans

4.4.3.1. Objectives and scope

The scope of the detailed model is dictated by the following considerations:

(1) the set of clientele groups it is to serve;

(2) the set of problems it is to address;

(3) the kinds of information it is to generate.

In addition, it is important that the resulting model be usable both as part of the FAP international trade system and as a "stand alone" model capable of addressing a wider range of issues than that covered by either the FAP system or existing US Department of Agriculture long-term projection models.

The model is intended to generate projections of value to a broad range of clientele groups. These include decision makers and their staffs in the executive and legislative branches of both federal and state governments as well as in the private sector. It is also considered to be of potential value to international decision makers working on problems involving commodity agreements, international loans, development policies, etc. Furthermore, it is anticipated that the model will be of considerable value to scholars, policy analysts, science advisors and consultants concerned with the condition and direction of the food and agriculture sector.

No model can attempt to provide the information required to solve all problems of interest to these clientele groups. Our ambition for the model is a more modest one: that it provide only a well-defined part of the information required to solve a well-defined set of problems, i.e., that it be a subject matter model. One subset of such problems concerns changes in the productive capacity of US agriculture in the short, intermediate, and long term, including problems of water, land, energy, and environmental quality. Other subsets involve price policies with respect to both food production and related policies of government controls over agricultural credit and the production, marketing, and trade of agricultural commodities. Science policy problems are crucial, since scientific and technological advances are major determinants of US agricultural productivity. Finally, the model is also being designed to address the large number of US policy problems concerning food and nutrition abroad as well as at home.

Information will be generated with respect to the behavior through time of a list of performance variables. Among the performance variables will be those in the new version of the US national agricultural accounts. It has been widely agreed that many of the traditional indexes or performance variables maintained for US agriculture are out of date. The model will generate projections concerning some of those old indexes which are retained and will attempt to generate projections with respect to the new performance indicators which are being developed both within and outside this modeling effort. Supply-and-disappearance and price tables will also be generated for important commodity groups. Other performance variables will involve nutrition status, foreign trade, balance of payments, macroeconomic variables, demographic variables, farm income and expenditures, and resource use.

4.4.3.2. System overview

A brief overview of the detailed US model is given in terms of its time orientation, policy content, commodity coverage, component structure, and flexibility.

For the purposes outlined above, the model needs to be particularly applicable for policy analysis over the intermediate-to-long term, say a five-to-15-year horizon. It will also be expected, however, to pass scrutiny in the one-to-five-year range and even be useful for analysis at that level.

Commodity- and sector-specific policies and scenarios are explicitly considered in the model, some as completely exogenous specifications and others as decision rules guiding endogenous adjustments over time in response to simulated conditions. Thus, scenarios, exogenous policies, and decision rules are specified in a Scenario Design stage, resulting in policy inputs to specific components. For example, scenarios concerning unprecedented technological advances – perhaps constructed from Delphi or other such processes in the Scenario Design – will influence crop and livestock supply; public investment in irrigation or soil conservation practices will influence the quality and quantity of land resources; commodity set-asides and support prices will affect production; and quotas, tariffs and reserve policies will have an impact on agricultural demand and prices.

On the supply side of the detailed model, 31 commodities and commodity groups are defined, while 29 are considered on the demand side. These are aggregated to the 19 traded commodities in the FAP's system. While nonagriculture is currently to be modeled in the aggregate (one commodity for supply and four for consumption), it is anticipated that in later extensions of the model we shall want to disaggregate it to emphasize sectors important to agriculture, e.g. various food processing sectors, marketing, transportation, fertilizer, fuels, machinery and other agricultural inputs.

The major components of the model include the following.

(1) Resource Development – which models changes in potential cropland and cropping intensity, irrigation, and environmental quality

(2) Crop Supply – with acreage and yield equations to project crop production consistent with cropland constraints

(3) Livestock Supply – which models the dynamics of herd demography to project animal numbers and the supply of livestock products

(4) Agricultural Finance – which computes farm accounts (e.g. income, sources and uses of funds, and capital gains statements) and productivity and other indexes, and variables necessary to link agriculture with the macroeconomy

(5) Nonagricultural Supply – which projects production of the nonagricultural sector

(6) Macroeconomy – which models aggregate income, investment, consumption, and national fiscal and monetary accounts

(7) Demand – which determines demand for each agricultural and nonagricultural commodity by demand category (human consumption, industrial consumption, feed, seed and loss, and stocks)

(8) Price–Quantity Equilibrium – which computes domestic equilibrium prices and quantities demanded consistent with world prices and the national budget

In addition, a demography component projects population and labor force, and accounting components apportion agricultural production to the states and compute consumer nutrition and expenditure accounts.

Another desired characteristic of the model is that it be flexible. For a model to remain useful and credible, it must be treated as an evolving capital asset. It is a capital asset because it is a durable from which a flow of services can be extracted. Such a model is a durable with high time costs, however, in that it can quickly become obsolete for policy analysis purposes. Therefore, this durable must always evolve to continue to address the policy issues of concern to decision makers, to generate the performance variables of interest, and to reflect faithfully the relevant behavior of its real-world counterpart – as all these change over time. Therefore, it is important for the model to be constructed in such a way as to facilitate rather than hinder the later improvements and extensions undertaken as part of that evolutionary process.

Another type of flexibility that is also necessary for credibility is flexibility in use. That is, it must be easy to manipulate the model to input alternative scenario and policy assumptions – whether they involve changes to data or to equations – and to output various types of information in various formats.

Both types of flexibility have implications for both the mathematical model and the computer program. For the US model, this translates into a building-block approach to component development and integration, user-oriented data input and report–writer interfaces, and thorough documentation of the model and its computer program.

4.4.3.3. Some generalizations

It should be noted that the model to be created and the knowledge it will generate are to be multidisciplinary. This creates some difficulties for the modeling team which consists almost entirely of economists. It will be necessary to include information and variables from disciplines not ordinarily regarded as "economic." Specialization in the methods and techniques of a discipline such as economics, or a subdiscipline such as production economics or econometrics, is inappropriate. Moreover, because the performance variables are normative while many of the structural variables are positive, a philosophic eclecticism which permits the model to be normative as well as positive will be essential. Further, it is important that the modelers and analysts building and using this model be eclectic enough to utilize the pragmatic methods of, for example, institutional economists, industrial organization analysts, and economic historians. As a subject matter model providing only a part of the information necessary for making decisions and solving problems, however, it cannot be expected, in and of itself, to be prescriptive. However, most models of the type being built here are used by decision makers in iterative interactions with analysts. Such iterative interaction is not only an important source of both positive and normative information, but also generates the prescriptive information necessary for decision making.

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4.5. THE KENYA AGRICULTURAL MODEL

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4.5.1. Introduction

Since 1978 work has been in progress within the Food and Agriculture Program on developing a general equilibrium open economy model for Kenya. Kenya is a "small" country in that it does not significantly affect the world market. However, the world market has a major effect on all aspects of the Kenyan economy. The agricultural sector forms the backbone of the Kenyan economy in a number of ways.

- More than 80% of the population derives its livelihood from this sector. Between 1976 and 1995 the rural and urban labor forces are likely to increase from 4.0 to 11.2 million and from 1.0 to 3.1 million respectively. Many of these new "entrants" into the labor force will have to be absorbed into the primary and processing activities within agriculture.
- The agricultural sector accounts for more than 65% of the foreign exchange earnings of Kenya. This foreign exchange is essential for importing many noncompetitive goods which are crucial for the rapid development of the agricultural as well as the nonagricultural economy of Kenya. Furthermore, the balance of payments problem is critical. In 1973 60% of coffee export earnings were necessary to finance petroleum imports, whereas in 1979 the corresponding figure was 120%. The solution of this problem requires an increase as well as a diversification of agricultural exports.
- Another pressing problem in Kenya is that of income distribution and growth. Not only is there a wide disparity between average incomes in rural and in urban areas but also the distribution is highly unequal within these two areas. Equity and growth of incomes in the initial stages will depend on the development of the agricultural sector.
- The availability of agricultural land is limited. In some areas soil erosion and nutrient leaching have reached disquieting proportions. The soil of Kenya is an irreplaceable stock resource and will need to be carefully preserved, conserved and enhanced to support the population of the future.

This set of interacting issues calls for an integrated multiobjective planning approach to agricultural development in Kenya. In our modeling work we take particular account of the structure of Kenyan agriculture and the relevant domestic and trade policies. For example, the small farm/large farm dualism calls for explicit modeling of these two groups. The rural and urban demands have to be separately considered in analyzing specific food and nutrition policies. The question of export cropping, and, in particular, of how small farmers benefit from growing export cash crops as opposed to food crops is an area of concern.

In the following sections the important features of the supply model, the demand system, and an analysis of the importance of agricultural trade and its effect on small farmers are considered.

4.5.2. Supply Model

A two-stage approach has been taken to model separately the supply response of Kenyan farmers. In the first stage the Box–Jenkins methodology has been used in estimating farmers' expectation functions for price and/or yield or revenue and these estimates are subsequently used in an adaptive acreage response model. The results of this study showed that small and large farmers are responsive to expected price and/or to expected yield or expected revenue. (The methodology and results for all small- and large-farm crops separately are given in Shah and Narayana, 1981.) As an example, the observed and estimated acreages for maize and coffee for small and large farms are plotted in Fig. 1. In the case of coffee, we found that the large-farm coffee area affected the small-farm coffee area and vice versa. This may be because of the International Coffee Agreement production quotas as well as the government policy of encouraging the participation of small farms in coffee production. In view of the simultaneity in acreage allocation between small and large farms, a two-stage least squares estimation procedure was used.

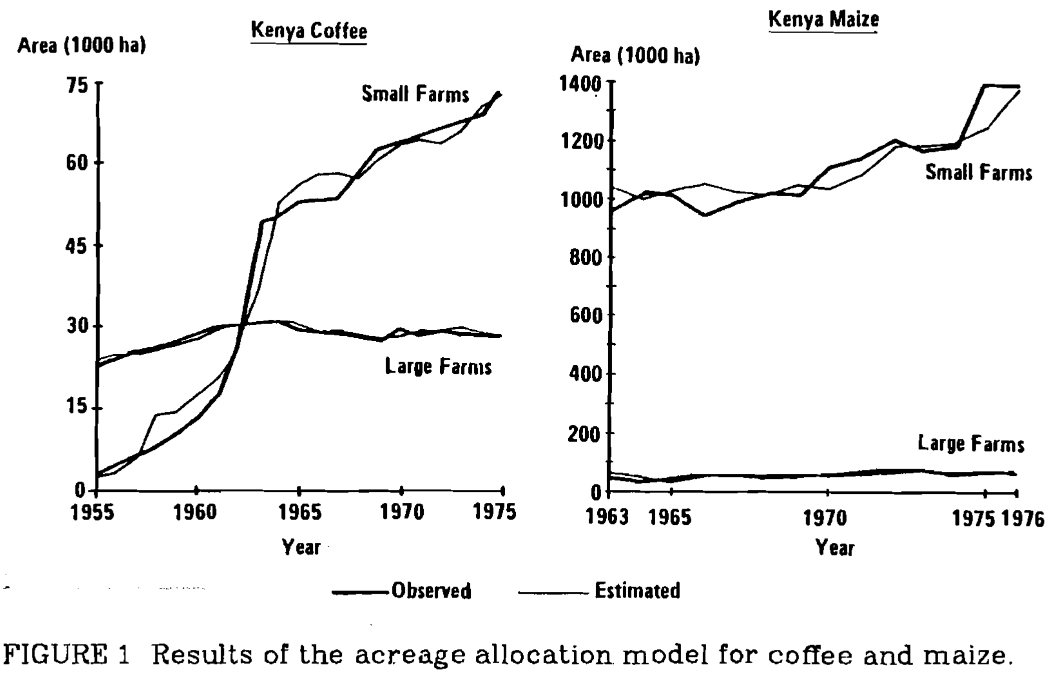

FIGURE 1 Results of the acreage allocation model for coffee and maize.

In the second stage of the supply model, given the area under each crop, farmers allocate inputs (fertilizer, labor, etc.) to different crops to maximize profit. Time series data on inputs by crops are not available. Our approach to the estimation of yield functions was to use an allocation and yield estimation model. (For full details of the methodology and results for all crops, see Fischer and Shah, 1981.) As an example, the results for coffee and maize are given in Fig. 2.

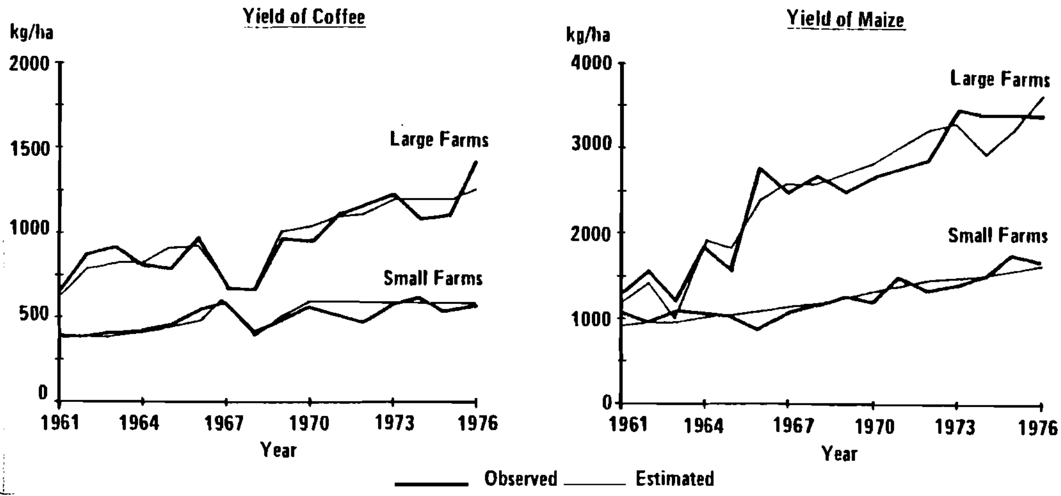

FIGURE 2 Results of the yield response model for coffee and maize.

The small-farm and large-farm separate supply response models, in terms of a two-stage approach, are suited to the analysis of specific government policies on producer prices and inputs. The validation of the supply model results over the period of estimation has been carried out and at present the ex post forecasting capability of the model is being tested.

4.5.3. Demand System

Our approach to the analysis and modeling of the rural and urban demand system has focused on:

- the analysis of food consumption and changes in food consumption over time
- policy formulation and the estimation of income and price elasticities
- a model of the complete demand system to fit the IIASA/Kenya model

Time series data on food expenditure surveys for Kenya are not available. We have relied on cross-sectional surveys comprising four urban, two provincial and one rural survey. We consider a partial equilibrium analysis (formulation of commodity-specific policies), linear expenditure system and the almost ideal demand system (AIDS). A cross-sectional analysis and a cross-sectional time series analysis were carried out. (For the results for expenditure shares, own and cross price elasticities, etc., for rural and urban Kenya, together with the methodology, see Williamson and Shah, 1981.)

4.5.4. Export Cropping and Benefits for Small Farmers

Between 1961 and 1976, the share of agricultural exports in total exports declined from 85% to 65%. The "oil crisis" after 1973 led to a rapid deterioration in the terms of trade but the international coffee price increases after 1976 led to a rapid upturn. In volume terms agricultural exports, especially tea and coffee, have increased rapidly over this period.

Kenya has encouraged small farmers to cultivate exportable cash crops. Sometimes this policy has been criticized as one that may have reduced rural welfare by reducing the availability of food in rural areas, even though small-farm incomes may have increased.

In the context of Kenya we wish to analyze the gain or loss to the small farm from export cropping. Tables 1 and 2 give the relevant data. We have considered four main export crops and the results are summarized in the following.

TABLE 1 Export cropping of coffee, tea, pyrethrum and sisal in Kenya, 1961 and 1975 (the percentage share from small farms is given in parentheses).

	1961	1975
Area (1000 ha)	196 (10)	267 (50)
Labour (1000 people)	195 (10)	261 (56)
Fertilizer (1000 m.t)	22 (1)	32 (9)
Export (K£M)	20 (17)	70 (41)
Maize Imports equiv. (1000 m.t)	925	1228
Potential (1000 m.t)	311 (10)	791 (43)
Potential (K£M)	6	17
Export Crops/ Food Imports	5.34	5.11

Table 1

- From 1961 to 1975 the export earnings from these crops increased from 20 to 70 million Kenyan pounds. During this period the share of small-farm production increased from 17% to 41%.
- If these foreign exchange earnings were used to import maize, at cost, insurance and freight via the Kenyan port of Mombasa, then in 1961 0.925 million tonnes of maize could have been imported (Table 1). In 1975 the corresponding figure is 1.228 million tonnes. However, if the land, labor and fertilizer resources in cash crop production had been used for maize production then in 1961 and 1975 these would have amounted to 0.311 and 0.791 million tonnes respectively.

The results show that the strategy of exploiting comparative advantage and promoting export cropping has been a good one. The value of all food imports in 1961 and 1975 could have been financed by less than 20%

TABLE 2 The benefits of export cropping for Kenyan small farms, 1961 and 1975.

SMALL FARMERS' NET REVENUE KShs./ha	1961	1975
Food Crops	428	1002
Export Crops	3424	4302
Food/Export Crops Strategy	451	1136
Food Strategy	–	1027

Rural Food Price Index (1961–75) = 1.647

INCREMENTAL ANNUAL GAIN IN SMALL FARMER REVENUE	
Food/Export Crop Strategy (Actual 1961–75)	3.08%
Food Strategy (Alternative 1961–75)	2.34%

of the export earnings of the four cash crops considered here.

Table 2

Table 2 shows the calculation to estimate the benefit or loss to the small farms as a result of growing the four cash crops, as considered in the foregoing. The strategy of growing food and export cash crops led to incremental annual gains in small-farms revenue of 3.08% compared with 2.34% for a strategy of growing food crops only. In the latter strategy we have assumed that the resources allocated to the production of the four cash crops are used instead for food production.

These simple calculations suggest that small farms have gained in real terms by participating in the Kenyan export cropping strategy. Detailed, integrated analysis of income, consumption, investments and employment effects for the small farmers will be explicitly possible within the IIASA Kenya model.

4.5.5. Concluding Remarks

The Kenyan model consists of a number of submodels. The development of some of these submodels, namely population and demography, crop supply response, demand system, food/nutrition, government and policy framework, marketing system, resources, ecology, and technology, has been reported in various publications (see references). At present, work on the development of submodels for livestock, rural and urban nonagriculture, government, and income distribution is in progress. All submodels are scheduled to be complete by mid-1981 and a linked model for policy analysis and projection will be ready by the end of the year.

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4.6. A NOTIONAL MODEL OF CHINESE AGRICULTURE

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The largest population of the world (1 billion in 1980) should be supplied with more and better goods for consumption in the future. This means that not only have new economic policies had to be introduced, but at the same time China has become an important factor in the world, with special impact on the grain market. As the lack of data precludes the building of a detailed policy model, a simple, notional model has been formulated. Its purpose is to give a rough idea of how the nutritional situation and foreign trade (especially grain imports) might develop in China.

Some of the basic problems of Chinese agriculture are as follows:

- the area of arable land available can be increased very little, and then only at a very high cost
- although much has been invested (mainly human labor) in irrigation in the past few decades, further development of irrigation is needed; this will be very expensive
- increasing the sown area by increasing multiple cropping is limited by climatic constraints, but also entails high investment costs and much time (rice transplanters, biological research on the shortening of growth time, etc.)
- possibilities of increasing yields through traditional agricultural techniques (which are very labor-intensive) are nearly exhausted
- the main source of yield increments in the last decade was the use of chemical fertilizer, although this is still relatively low (50 kg nutrient/hectare). This could serve well in the future also, but would require either high investments in fertilizer plants or high imports.

All these problems show that agricultural investment is of high priority in promoting agricultural growth. In addition, the importance of modernization through the introduction of new technologies (especially in the nonagricultural sector) is stressed. This might require high levels of imports of advanced-technology goods. Thus two financial problems arise: how to meet high investment requirements and how to finance increasing imports.

In the past, China has been able to finance her imports by exports and by taking out some medium-term foreign loans; thus foreign trade, with the exception of some years, was balanced. But if imports continue to increase at the rate of recent years, China may require long-term foreign loans. Access to foreign credit may be improved, however, since China joined the International Monetary Fund and the World Bank.

4.6.1. Description of the Model

The model is mainly based on the FAO Supply Utilisation Accounts, but considerable use has also been made of other information. In particular, Tang's study (1978) on agricultural development and Aird's population models (1978) supplied valuable data.

The FAP model of Chinese agriculture uses the 10-commodity aggregation of the basic linked system (with which it is compatible), with one difference: on the supply side, cotton is treated separately owing to its importance in China.

The model has been created to show the mutual influences of the requirements of supplying enough food for the population, investing to be able to ensure adequate production in the future, and keeping foreign trade balanced.

The structure of the model is shown in Fig. 1. The details of the various blocks are described in the following.

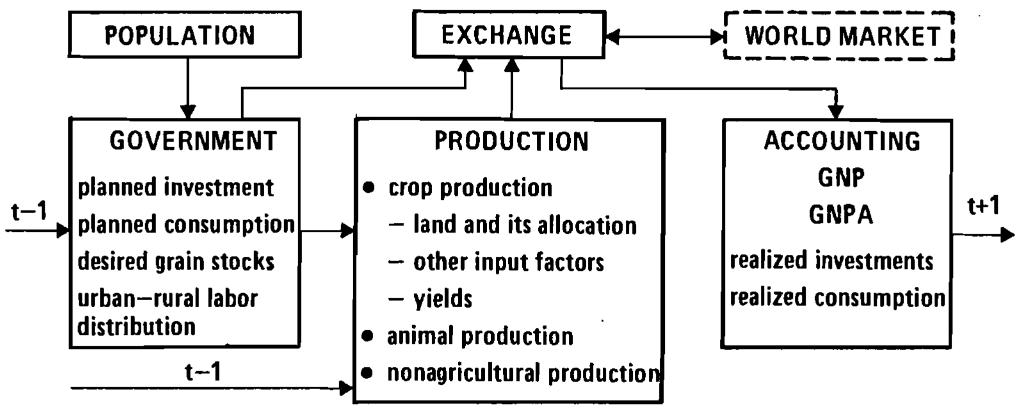

FIGURE 1 The structure of the Chinese agricultural model.

The *population block*, which includes estimates of population and work force, is exogenous to the model.

The *government block* includes:

- planned gross investments as a function of the previous year's GNP or as an exogenously given investment rate
- the investment allocation between the two sectors (agriculture, nonagriculture) as specified by a policy variable
- planned food consumption, according to trends of per capita food consumption, or according to exogenously given growth rates
- planned consumption of nonfood items, determined by exogenously given growth rates

- desired grain stocks, computed on a per capita basis
- the urban–rural labor distribution, which assumes a maximum possible growth rate of urban jobs and allocation of the remainder of the total work force to the agricultural sector.

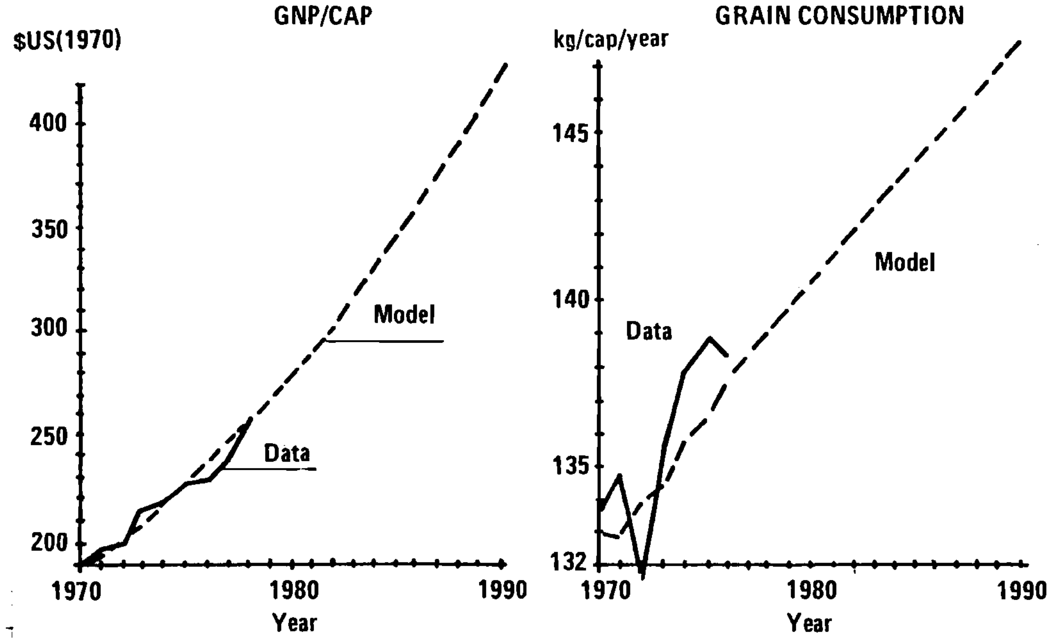

FIGURE 2 GNP per capita and grain consumption in the reference run.

The *production block* deals with the following inputs: land, irrigation, organic and chemical fertilizers, and mechanization. These are computed either as functions of capital stocks or as trends.

- The total sown area is determined by the cultivated area (which is constant or increases at some exogenously given rate) and by the index of multiple cropping. (The latter is a function of mechanization, irrigation and time.)
- The allocation of land to the crop commodities considered is carried out according to autoregressive schemes, which describe the development of the area shares. As these estimates are independent of each other, a complete allocation of total area is reached by an adjustment mechanism, assuming that self-sufficiency per crop is desired. In some simulation runs area-switches among crops can be introduced as well.
- Yields are determined for the main crops (wheat, rice, coarse grains and cotton) as functions of fertilizer application and irrigation. Yields of other crops are treated as time trends.

- Animal production is determined by the grain availability for feed and by trends.
- The nonagricultural production is a Cobb–Douglas function (with constant returns to scale) of urban labor force and nonagricultural capital.

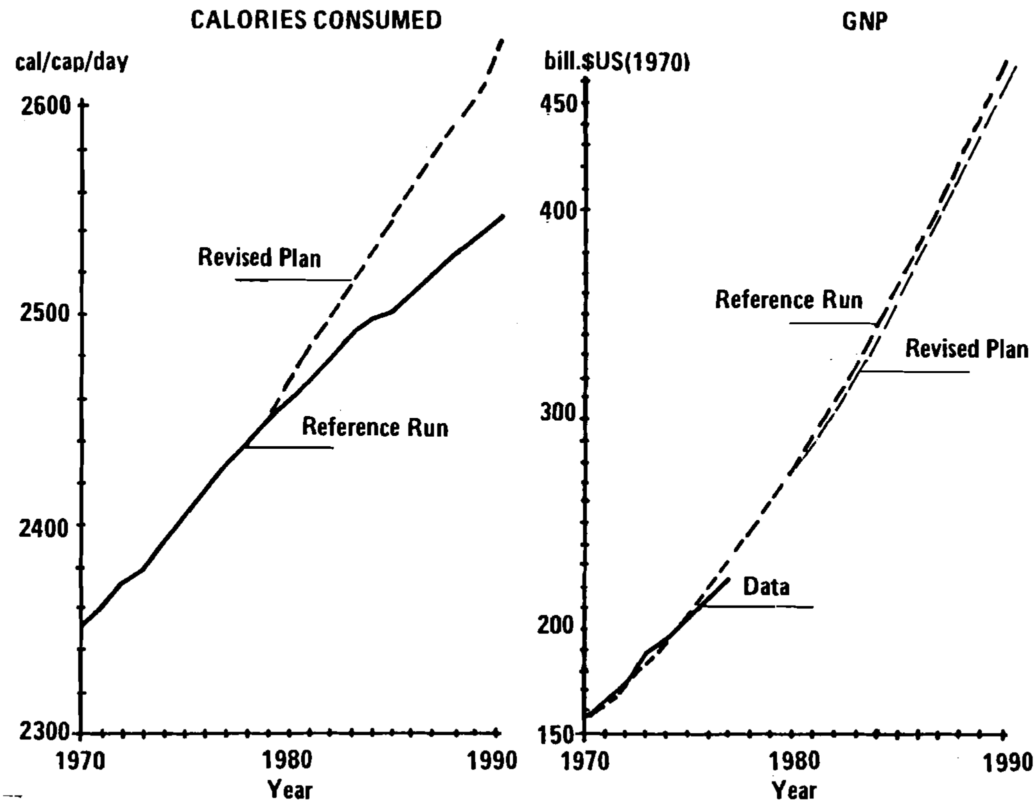

FIGURE 3. Comparison of calories consumed and GNP in the reference run and in the revised run (lower population growth, agriculture preferred to industry, higher consumption of animal proteins).

The *exchange block* uses the same balancing routine as the Hungarian agricultural model (see Csáki, 1979) and the CMEA model (see Csáki, forthcoming). For the 10 commodities considered, noncommitted demand (in our case planned consumption, desired stocks, feed requirements and planned investments) is compared with net endowments (net production, intermediate consumption and previous year's stocks), both evaluated at world market prices. For the different demand groups, ranges of allowed deviations from the given targets are prespecified. A priority order that expresses the importance of a given target to be reached is also given. The exogenously given balance of foreign trade is considered as well. As a result, net exports of commodities are determined.

After exchange has taken place, an *accounting block* computes realized consumption and investments, calories, amount of protein consumed, capital stocks, etc., and the model enters the next year.

4.6.2. Preliminary Results

Several simulation runs have already been carried out. Some results of the reference run are shown in Fig. 2. In a revised run, lower population growth is assumed; a policy of preferring agriculture over industry when investments are allocated (in contrast to past practice) and of having a higher consumption of animal proteins is considered. The results are modified as shown in Fig. 3.

It should be emphasized that in both runs area allocation according to past patterns is assumed, and neither considers dramatic changes in animal production (and consequently in feed production and consumption). The elaboration of such further simulation runs, which should approximate to actual Chinese plans, will be the next step in the modeling exercise.

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4.7. A POLICY SIMULATION MODEL FOR THE POLISH AGRICULTURAL ECONOMY

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4.7.1. Introduction

Work on a simulation model of the Polish agricultural economy, started in the fall of 1979, had by February 1981 reached an advanced stage, with many components nearing completion. Like other models built under the auspices of IIASA's Food and Agriculture Program, the Polish model covers basic problems of the whole economy and not only those inherent in agricultural production. Although the model's characteristics follow the patterns present in other FAP national models, some differences reflecting peculiarities of Polish agriculture and specific policy issues do exist. Probably the most important is the fact that some parts of the model are not very descriptive in character (defined in terms of the model's capacity to explain the past). Instead they constitute what seem theoretically motivated proposals for definite changes in the structure of the economic mechanisms operating in Poland. Practical adaptation of the proposals in the course of impending reform, which may be deemed quite possible, would therefore result in the restoration of the descriptive nature of the whole model (defined in terms of the model's capacity to predict the future).

There are three versions of the model, each serving a specific purpose.

- a dynamic simulation model with modules making endogenous various government policies (this version is linkable to the FAP system in a straightforward way)
- a yearly general equilibrium model that allows the simultaneous optimization of various government decisions affecting the yearly performance of the economy, special emphasis being put on agricultural production, consumption of food and distribution of welfare (this version is intended for the rationalization of short-term government policy making)
- a multiperiod (intertemporal) general equilibrium model that allows a synchronization of optimum government decisions for separate years over longer periods (this version is intended for rationalization of long-term government policy making)

The three versions differ therefore mainly in respect of the degree of simultaneity allowed for. Since it is relatively easy to transform a "more simultaneous" model into a "less simultaneous" model, it is expedient to present some features of the general equilibrium models. The "agents" discerned in the model are groups of consumers (differentiated by levels of income), groups of farmers (differentiated by technologies and by levels and compositions of the means of production) and sectors of the rest of the economy (with separate industries supplying agriculture and separate food processing industries considered explicitly).

There are some novel elements allowed for in comparison with other general equilibrium models. The most important is the fact that the subsectors of agriculture (groups of farmers) are described by linear programming (LP) models ("aggregative" models). While a number of other national agricultural models also adopt the LP description of the sectors, they are not set in the context of general equilibrium considerations. Instead, they assume that certain disequilibrium processes – expressed by exchange following production – take place. Since the LP description of the sectors implies the possibility of the non-uniqueness of the (competitive) equilibrium, and in some cases even its absence, there may be a need for the introduction of quantity constraints: limits on the availability of inputs and quotas on production. The model provides for the consistent simultaneous determination of both prices and quantity constraints while fully respecting the sovereignty of the profit-motivated behavior of the subsectors of agriculture.

Another important fact is the simultaneity in the treatment of investment and production decisions of the subsectors of agriculture. This is achieved by making the LP models for the subsectors dynamic. (In fact the LP models are dynamic LP models with two periods distinguished.)

There are also some innovations in the description of the demand side. The hypothesis maintained is that of the Extended Linear Expenditure System. However, the direct substitutability of various foodstuffs is taken into account (through the introduction of subsistence levels of intakes of particular nutrients). Also, savings are related to the rate of interest on money deposits.

4.7.2. The Structure of the Dynamic Simulation Version of the Model

In this version of the model there are eight main submodels, each describing a specific process taking place within any year of the simulation period. Their sequence in a yearly run of the model is as follows:

(1) multiperiod macroeconomic planning

(2) yearly macroeconomic input–output planning

(3) nonagricultural production

(4) agricultural production and control of agricultural production

(5) revision of macroeconomic plans on consumption, foreign trade, investment, and stocks

(6) consumption and incomes by groups of population and control of consumption and incomes

(7) agricultural investment, reallocation of land among subsectors of agriculture, and control of agricultural investment

(8) intra-agricultural migrations, outmigration from agriculture, demography, labor mobility

4.7.2.1. Multiperiod macroeconomic planning

Inputs*: long-term desired trajectories of the main macroeconomic indicators, long-term forecasts of terms of trade and demographic developments.

Outputs: five-year plans on production, investment, foreign trade, and consumption by major sectors of the economy.

Character of the module: The multiperiod multisector optimization model with reference trajectories serves as the basis for the specification of the criterion function. Technical coefficients are derived from available input—output analyses. Econometric estimates are made of parameters describing labor mobility and gestation periods.

4.7.2.2. Yearly macroeconomic input—output planning

Inputs: the segments of the five-year plans related to the macroeconomic activities of a specific year.

Outputs: macroeconomic (yet more disaggregated) plans for consumption, production, employment, investment, foreign trade, and stocks by major sectors of the economy.

Character of the module: static, linear programming, multiple-objective (reference point) optimization model.

4.7.2.3. Nonagricultural production

Inputs: production plans by major nonagricultural sectors.

Outputs: production by major nonagricultural sectors, use of inputs (labor, intermediate inputs).

Character of the module: this implies a simple arithmetical operation.

4.7.2.4. Agricultural production (and control of agricultural production)

Inputs: desired levels of agricultural production, supplies of intermediate inputs for agriculture (imported feedstuffs and goods, services originating in nonagricultural sectors), weather conditions.

Outputs: agricultural production (net, global) by products and type of farming, prices for agricultural products and their raw materials, overall profitability of production by types of farming, quotas on production and limits on input availabilities.

Character of the module: a two-level coordination procedure involving prices and – if need be – quotas for production and limits on the use of inputs. The upper level of decision making is described as an optimization with respect to prices and quantity constraints applicable to the lower levels (subsectors of agriculture defined as types of farming). The constraints of the upper-level optimization model reflect the global constraints on production and use of intermediate inputs by agriculture, constraints on price changes, and postulated levels of profitability of the

* Beside inputs and outputs listed together with the main submodels there are lagged inputs and outputs representing recursive (dynamic) links of the model. Since these are basically mechanistic in nature (as standing for the updating equations), they are not discussed.

subsectors. Owing to additional constraints, the assumptions of the unhampered profit motive for the subsectors are satisfied, and at the same time speculative phenomena are prevented. The lower-level decision making is described by separate linear aggregative (sectoral) models for private traditional, private modern, private part-time, state-owned and cooperative farming. Each of the sectoral models is characterized by significant levels of technological and environmental precision in the adopted definitions of activities and constraints (e.g. three types of soil are distinguished).

4.7.2.5. Revision of macroeconomic plans on consumption, foreign trade, investment, and stocks

Inputs: macroeconomic yearly plans on consumption, foreign trade, investment, and stocks, nonagricultural production by sectors, agricultural production by products, use of imported raw materials, actual world market prices (the latter from the FAP World Model).

Outputs: actual trade, stocks, investment (by sectors), revised plans for investment (by sectors) and total consumption of major nonagricultural and all agricultural products by the population.

Character of the module: this is similar to that of module 2.

4.7.2.6. Consumption and incomes by groups of population (and control of consumption and incomes)

Inputs: pretax incomes of particular groups of population and revised plans on consumption by total population of major nonagricultural and all agricultural products.

Outputs: retail prices of major nonagricultural and all agricultural products, taxation of incomes of all groups of population, and consumption and savings by all population groups.

Character of the module: this implies a two-level coordination procedure involving retail prices, taxes, and rate of interest on savings. The upper-level decision making is described as a multiobjective optimization model with reference objectives representing desired patterns of consumption for various groups of the population.

The lower-level decision making is described by a separate utility maximization problem representing generation of demand from various groups of the population. The demand systems adopted can be defined as thrice-modified linear expenditure systems. (The major modifications involve the introduction of the direct substitutability of various food commodities, and the inclusion of the effects on savings of changing rates of interest.)

4.7.2.7. Agricultural investment, reallocation of land, and control of agricultural investment

Inputs: marginal profitabilities of land and particular capital goods and financial assets by different types of farming, total investment in agriculture provided by the revision of macroeconomic plans on consumption (by types of capital good).

Outputs: size and structure of investment by type of farming, reallocation of land and capital goods within agriculture, and production potential by types of farming.

Character of the module: this is similar to that of submodel 4.

4.7.2.8. Demography, labor mobility, migration

Inputs: disparities in incomes, standards of living and economic prospects for population groups.

Outputs: availability of agricultural labor force for nonagricultural and agricultural production (by type of farming), permanent outmigration.

Character of the module: the module is demographic and econometric.

4.7.3. Institutional Background of the Work

The work on parts of the model is being done by Polish scientists from the Institute of Agricultural Economics, the Systems Research Institute and the Institute of Rural and Agricultural Development. The sponsorship is provided by a Council consisting of the Directors of the first two institutes, the Vice-Minister of Agriculture and the Minister for Agriculture in the Central Planning Office. At IIASA support is provided by the Food and Agriculture Program and the System and Decision Sciences Area.

4.8. AGRICULTURAL MODELS FOR EGYPT AND BRAZIL

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The study of Egypt and Brazil raises a number of issues of interest to planners in most developing countries. Over the last twenty years the two countries have followed quite different development strategies.

Egypt is a country of 41 million people with a rather low average GNP per capita of US$ 460 (1979). It has been characterized by relatively sluggish growth until recent years. There is a large (50%) government/public sector with guaranteed employment and relatively secondary consideration given to equity. Over the period 1960–78 it has achieved an annual growth rate of over 5%. It has made significant impact on world exports even in areas such as soy beans and, more recently, manufactured goods which have traditionally been dominated by the more developed countries .

4.8.1. Models

Models have now been developed for both these countries. Both are macro-models which place considerable emphasis on the agricultural sector. Each is based on a social accounting framework. The demand structure includes six income classes in the Egyptian case, while Brazil has two. Competitive and non-competitive imports are distinguished. Supply functions have been estimated for the agricultural sectors; production functions are used for the other sectors. For Brazil there are 21 agriculture subsectors; the rest of the economy is modeled by seven. One of these, for example, is energy. This facilitates the analysis of such current issues as the gasohol-petroleum program. The Egypt model has been described by McCarthy (1981) and by Eckaus et al. (1980). The production and consumption analyses for Brazil are available as working papers (Lopuch and McCarthy, 1981; Williamson and McCarthy, 1981).

4.8.2. Policy Analysis

A number of runs were made to simulate selected policy options.

For Egypt the removal of subsidies was considered. This policy has been under recent consideration. Some of the results are summarized in Table 1. We note the strong deflationary impact on the macrovariables listed. Other features of these results are the modest fall in food consumption and the large drop in demand for the relatively elastic textile industry output. Even here the richness of the model allows the relative impact on different classes to be investigated.

For Brazil a base run was compared with three policy options. The three policies chosen correspond to the allocation of 20 billion Cr. $ for agriculture subsidies (A), or manufacturing and service subsidies (M), or

TABLE 1 Policy run – remove consumer subsidies.

Imports	−3.2%
Gov. Deficit	−12.8%
GDP (Real)	−3.5%

Expenditure Category	PERCENT CHANGE Total Population	Low 60% U	Upper 10% U
Staple Food	−2.5	−2.6	−1.3
Nonstaple Food	−5.2	−8.9	−5.0
Textile Industry	−6.0	−17.4	−5.2

FACTOR DEMAND	PRIVATE SECTOR Labor	Capital	Land
Staple Food	−2.5	−2.5	−2.5
Nonstaple Food	−5.2	−5.2	−5.2
Transport and Communications	−7.6	−7.6	
Housing	−12.5	−12.5	

increased government services (GE). The ranking of the outcome of these policies is given in Table 2. Note that for real growth A seems best (ranked 1), but the impact on government surplus of this policy is not very good (ranked 4).

TABLE 2 Brazil – ranking of policies.

	Base Run	A	M	GE
Objective				
Real Growth	4	1	3	2
Balance of Payment	1	3	2	4
Govt. Surplus	1	4	3	2
Agric. – Empl	4	1	3	2
Services – Empl	4	3	2	1
Food Consumption				
Rural	4	1	2	3
Urban	4	1	3	2

Thus these models provide a convenient means of obtaining insight into various policy options. They also enable policy makers to have some advance warning of possible negative consequences. This may be allowed for in forming a final policy package.

4.8.3. Future Work

This work is currently being discussed with planners and policy makers in the two countries. The input is then being adapted to the current structure. In particular the modeling of the dynamics of capital formation and balance of payments modules is being improved. The overall structure of these models is modular; this structure lends itself rather well to the incorporation of new blocks or improved data as they become available.

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4.9. AN AGRICULTURAL POLICY MODEL FOR INDIA – AN ILLUSTRATIVE EXPLORATION OF A RIGHT-TO-FOOD PROGRAM

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4.9.1. Introduction

The problem of Indian agricultural policies is how to increase productivity for a land-scarce (40% of total land is already cultivated), labor-surplus, largely rain-dependent (only 30% of land is irrigated) agriculture, dominated by millions of farmers (55 million cultivator households, 12 million landless laborer households) with small landholdings (average size 2.5 hectares), in a populous (650 million), poor country (average income 150 US dollars/person/year) where scarce resources are required for developing other sectors of the economy as well. In addition, the income distribution is such that a large part of the increasing population does not even have a minimum nutritionally adequate diet. The development of the economy and of the agriculture sector has to be realized while attempting to meet the basic needs of the poor.

Planning and policy making in India are carried out in the context of a planned economy in which public and private sectors coexist, in which key industries are in the public sector, and in which agriculture is totally in the private sector. Five-year plans set targets for growth, output, and investment by sectors (separately for public and private sectors). Some key indicators of the development of the Indian economy are shown in Table 1.

TABLE 1 Average economic growth rates for India, 1960–70 and 1970–77.

	Growth rate, per cent per year		
		1960–70	1970–77
Per capita GNP		1.3	1.0
GNP		3.6	3.0
Agriculture		1.9	4.1
Industry		5.5	2.6
Gross domestic investment		5.6	2.1
Life expectancy at birth	1920:20	1950:32	1977:51
Population		1950: 359 million 1979: 650 million	

Plan targets are to be achieved through appropriate policies. However, plan documents do not specify these policies, and planning models do not include specific policy instruments to ensure that targets are reached. A policy model in which instruments are explicitly treated is required to analyze the efforts needed to realize the targets. For example, government can increase irrigation, increase support prices, and make available high yielding variety (HYV) seeds and fertilizers; but farmers decide what to grow and how. Thus we need to ensure that farmers' decisions would fulfill planners' expectations.

We describe here a model, along with some of the illustrative results obtained using the model, for evaluating alternative policies in the agriculture sector of the Indian economy. The model developed is a price-endogenous computable model of the general equilibrium type, intended to be used for year-by-year simulation. Our broad objective is to build a descriptive, computable model with which the consequences of various government policies can be evaluated, and these policies can be examined in the context of the open economy of India.

The model is structured both to reflect agriculture in India and to be computable with the empirical information available.

4.9.2. A Brief Description of the Indian Agricultural Sector

The importance of agriculture in India can be seen from the fact that nearly 40% of the GNP was generated in this sector in 1976–77. That part of the population which depends on agriculture (78,200,000 in 1971) constitutes 43.3% of the workers in the country. Another 26.3% of workers are agricultural laborers and 2.4% depend on livestock, fishing and plantations operations. In addition, agriculture is an important sector because estimates of the proportion of the population below the poverty line in rural areas in 1968–69 range from 43% (Minhas, 1970) to 54% (Bardhan, 1973). Here, the poverty line was taken to be a per capita consumption of 200 rupees (1960–61 prices) per year for rural areas.

Indian agriculture is dependent to a large degree on the monsoon, and fluctuations in this cause significant variations in output from year to year. In bad years the government has imported large amounts of foodgrains (6.5 million tons in 1976–77) and distributed them through fair-price shops to urban consumers. Also, the government procures foodgrains from farmers for running this public distribution program. The prices at which foodgrains are sought to be procured from farmers have been below the market price in bad years. The procurement price has, however, acted as a support price in very good years. The government has also tried in the past to prevent free movement of foodgrains in the country in order to seal off surplus areas and to facilitate procurement.

The sale price in urban ration shops, which has sometimes been lower than the government's cost, has been below the free market price and has thus provided a subsidy to urban consumers. A low stable food price is desired by the politically more vocal urban population. The public food distribution program has led the government to carry stocks of foodgrains from year to year. A bufferstock policy coupled with the policy of public foodgrains distribution can help in leveling out food prices, in containing inflation and in eliminating the need for large imports in certain years. Yet it is not clear to what extent the stocks carried by the government result from an active bufferstock policy. The broad objective of agricultural policy can be described as the attainment of self-reliant, sustainable growth with equity and price stability. Important policy instruments used in India for realizing the objectives are described in the following.

The Indian Agriculture Model (I-AM) for medium-term policy analysis examines the following policies:

(a) procurement/support prices
(b) public food distribution programs, with reference to the quantity procured, the amount distributed in ration shops, and ration prices
(c) bufferstock operations
(d) levels of taxes
(e) trade and tariff levels

and the impact of these policies on:

(a) production levels and composition
(b) distribution of income and food consumption
(c) price stability
(d) equity
(e) growth

In addition, some effects of changes in patterns of landholding and tenancy structure can also be explored, along with the effects of aid (and in particular food aid), which increase short-term availability but reduce production incentives.

The model developed permits evaluation of these policy instruments by calculating their impact on levels and distributions of consumption, production, trade, etc. In section 4.9.3 we describe the general structure of the model, which contains several submodels. For a discussion of the methodology for estimating the submodels, see Parikh and Narayana (1981). In section 4.9.4 the validation and calibration of the estimated submodels is presented, and in section 4.9.5 we present a few results.

4.9.3. The General Structure of the Model

The economy is represented by two broad production sectors: agriculture and nonagriculture. The latter is further split into rural and urban nonagriculture, although their outputs are not distinguished. We identify 16 major crops and nine minor crops in the agriculture supply model, along with several animal products; but since the consumer demand systems are available only at a relatively aggregated level, the productions are aggregated to have nine agricultural sectors to correspond to the FAP basic linked system. We distinguish 10 income classes – five rural and five urban.

Agricultural production is based on the land allocation decisions of farmers, which are based on the relative expected revenue of a crop compared with that of its competing crops, on irrigation, and on rainfall. The details of the estimation of supply responses are given in Narayana and Parikh (1981). Yields are functions of irrigation, fertilizer, rainfall, and time.

The economy is an open economy, and trade of both agricultural and nonagricultural goods is permitted. Income generation is endogenous. Income distribution in the agriculture sector is determined by the distribution of landholdings, parameters for which are exogenously prescribed. Demand for various products depends on income and relative prices and is characterized by a linear expenditure system estimated separately for each of the 10 income classes. (For details see Radhakrishna and Murty, 1980.) The relative prices are determined in the model within the framework of an exchange economy where domestic production is considered as fixed during exchange. There is no money in the model which can be held as a store of value. However, stocks of physical goods can be held. Savings and investment decisions are endogenous.

The government sector operates a number of policies such as tariffs and subsidies on trade, bufferstock releases of agricultural products, support prices and procurement levels and procurement prices. It operates a food rationing system for the urban population. All the operations of the government are carried out within its income.

Though the model will have many periods, the solution is carried out sequentially from period to period. Some policies, however, can be determined appropriately only in a long-term context. These would be assumed to have been so determined, exogenous to our model. In fact, simulation runs of the model should help in determining some of these policies.

Figure 1 is a schematic outline of the model. The model constructed is, in fact, a system of submodels which are interconnected. As an illustration, a schematic diagram of the agricultural supply submodel is shown in Fig. 2.

4.9.4. Validation and Calibration

The model has been estimated from data covering the period from 1950–51 to 1971–72. A simulation exercise was performed to see the behavior of the model for the period from 1971–72 (the Indian financial year runs from April to March) to 1975–76 (nominally we refer to 1971–1975). For this run we specified the following:

- the actual prices were fixed as targets
- the trade levels were constrained to be within ± 5% of the actual trade for each sector
- the world market prices, the balance of trade, and aid levels were specified at actual levels
- the stock levels were kept free to adjust

The first results produced stock levels and prices which did not compare well with actual values. Our demand systems were estimated in terms of wholesale price indices. To convert them to market prices we had to use base year market prices. Since our information on this was weak, we used adjustment of the base year prices to calibrate the model. This new adjustment has the effect of changing committed demands.

As a result of these adjustments we obtained reasonable prices and stock levels. Unfortunately, data on private stocks are not available, and the resulting total stocks can be compared only to actual public stocks. These results are shown in Tables 2 and 3 and seem very encouraging.

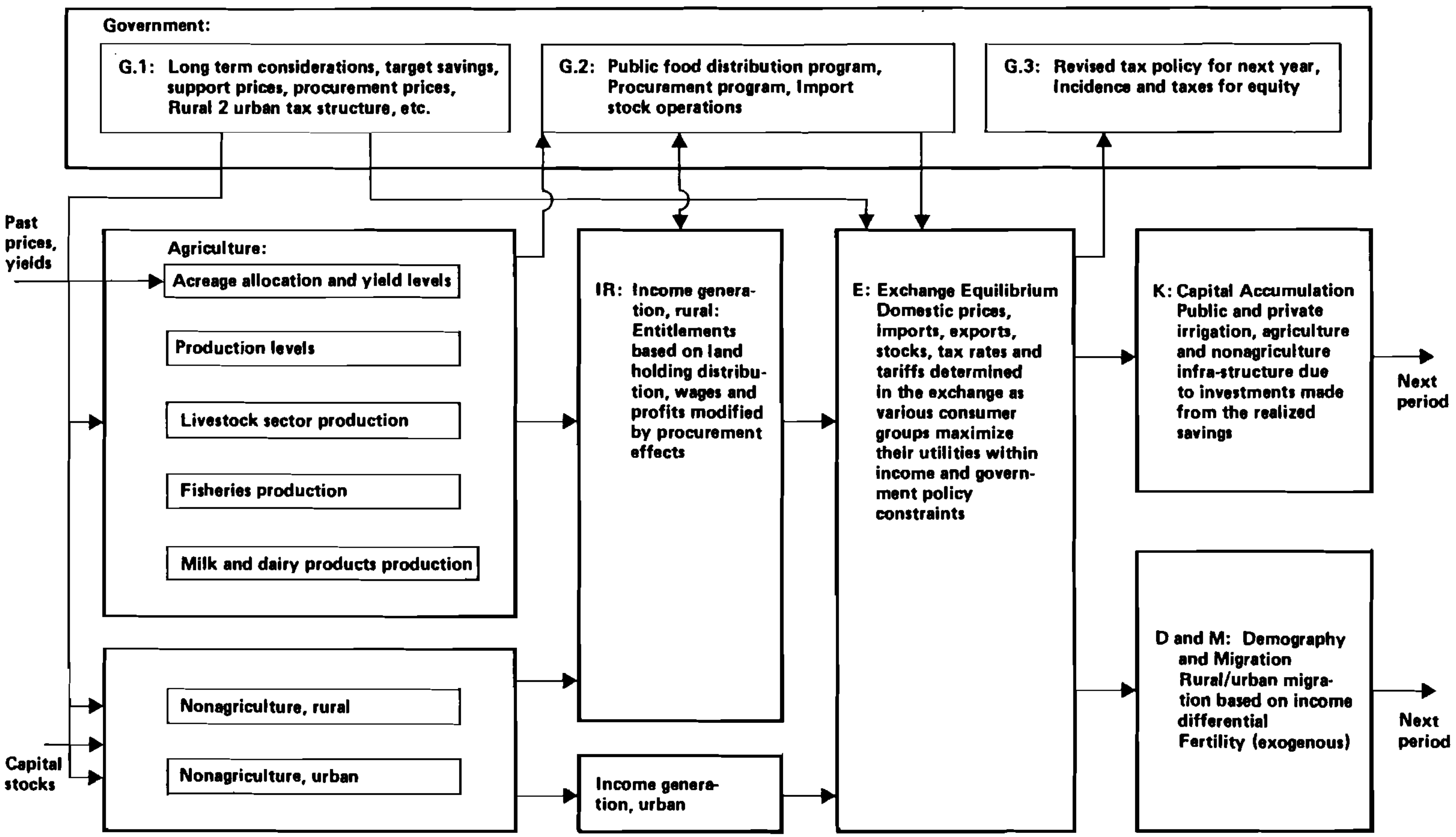

FIGURE 1 A schematic outline of the Indian Agricultural Model.

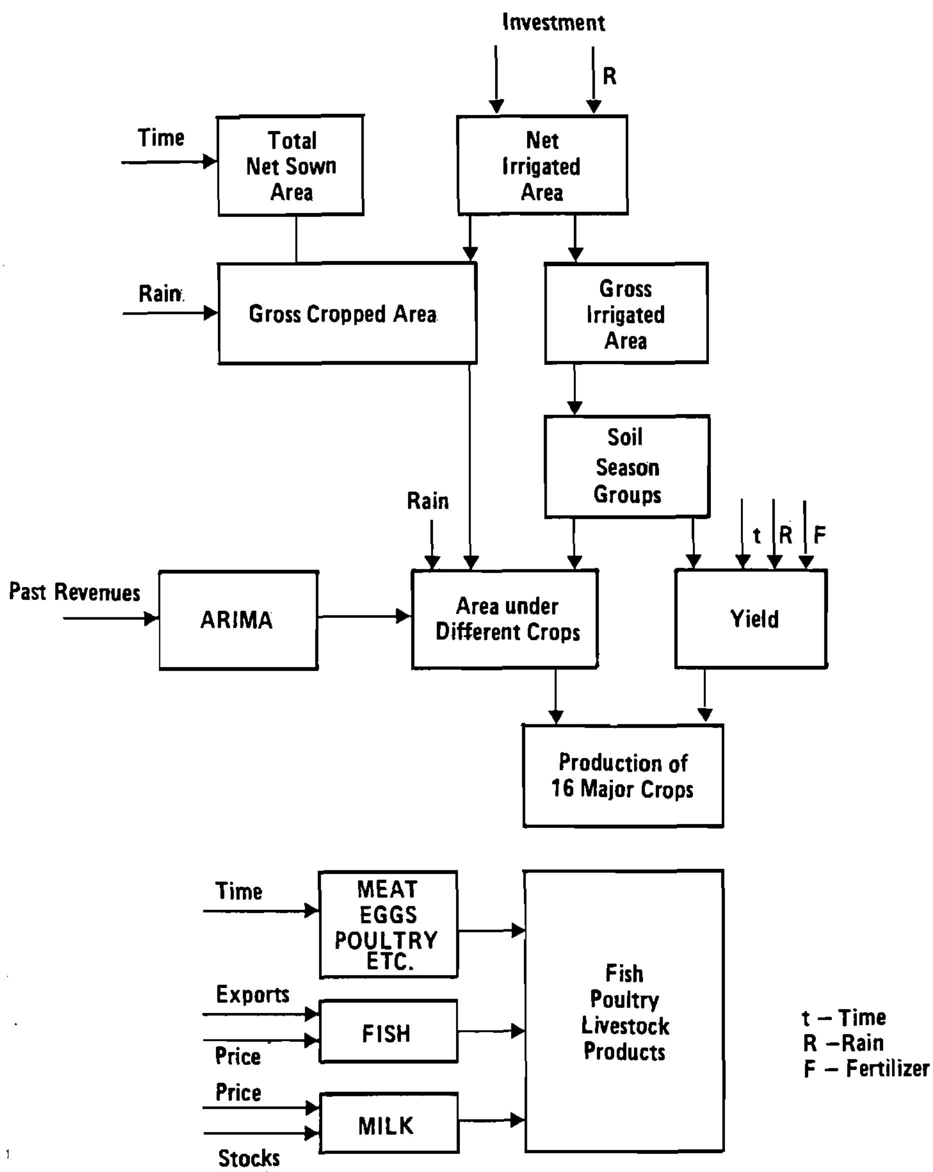

FIGURE 2 The agricultural production module of the Indian Agricultural Model. (ARIMA: autoregressive integrated moving average)

4.9.5. An Illustrative Policy Analysis

To illustrate the kind of results this model is capable of generating, we ran four scenarios (this is too few to derive any firm policy conclusions, we emphasize). The scenarios were designed to test one policy that we call the "free food" program, in which the government annually distributes freely to everyone 75 kg of foodgrains as a way to redress immediately poverty and malnutrition.

TABLE 2 Prices in India, 1971–1975. I-AM: static simulation/validation (realized price/target price).

Sector	1971	1972	1973	1974	1975
1. Wheat	*	*	*	*	*
2. Rice	*	*	*	*	2.67/2.14
3. Coarse grains	*	*	*	*	*
4. Meat	*	*	*	1.61/1.57	*
5. Dairy	*	*	*	*	2.59/1.89
6. Poultry, fish	22.3/15.1	*	*	*	32.5/23.0
7. Protein feeds	*	*	*	*	*
8. Other foods	*	*	*	*	*
9. Nonfood agriculture	*	*	*	*	*
10. Nonagriculture	*	*	*	*	*

*Realized price = target price.

TABLE 3 Food stocks in India, 1971–75. I-AM: static simulation/validation (realized *total* stocks/actual *public* stocks).

Sector	1971	1972	1973	1974	1975
1. Wheat	2.1/3.1	2.3/5.0	4.8/1.9	1.5/1.0	4.5/1.2
2. Rice	5.6/1.8	4.1/2.3	0.4/1.4	1.5/1.4	0/2.8
3. Coarse grains	3.6/0.4	2.5/0.5	0.14/0.15	2.5/0.5	0.68/0.22
4. Meat	0.27/0	0.25/0	0.2/0	0.16/0	0/0
5. Dairy	3.0/0	3.0/0	1.8/0	0/0	0/0
6. Poultry, fish	0/0	0/0	0/0	0/0	0/0
7. Protein feeds	0/0	0/0	0/0	0/0	0/0
8. Other foods	0.58/0.17	0.34/0.07	1.3/0.1	1.3/0.1	0.33/0.15
9. Nonfood agriculture	0.60/0.08	0.5/0.13	0.27/0.11	0.27/0.19	0.16/0.16
10. Nonagriculture	0/0	0/0	0/0	0/0	0/0

The questions that arise are the following.

- What would be the impact on poverty, on consumption, and on income distribution?
- What would be the impact on government budget, its budgetary surplus, and public investment, and consequently the impact on the growth rate of the economy?
- What would be the impact on domestic market prices of foodgrains and their impact on supply?

The special characteristics of the four scenarios are described in Table 4.

The simulation is carried out from 1971 to 1990, where for the period 1971–76 a static simulation is performed and policy changes are introduced in 1977.

To eliminate the problem of domestic supply disturbances, we ensure the same prices to farmers – i.e., the same incentives – in all scenarios,

TABLE 4 Indian Agricultural Model scenarios.

• **Low growth base**	• **High growth base**
– savings rate lowered	– savings rate on trend
• **Free food distribution from 1977**	• **Free food distribution from 1977**
– Financed by lowered investment	– Financed by lowered investment

TABLE 5 Indian Agricultural Model results: annual growth rates, 1971–90, and calorie and protein consumption, 1976–90.

	Annual growth rates (1971–90)(per cent)			
	High growth		Low growth	
	Base	Free food	Base	Free food
Real GDP	5.40	4.77	4.60	3.86
GDP Agriculture	2.59	2.59	2.59	2.59
GDP Nonagriculture	6.95	6.07	5.78	4.70

	Calorie (protein) consumption per person per day in kcal (grams)			
	High growth		Low growth	
Year	Base	Free food	Base	Free food
1976	2560(68)	2560(68)	2560(68)	2560(68)
1980	2697(70)	2821(74)	2776(72)	2897(76)
1990	2727(72)	2727(72)	2821(74)	2827(74)

through complete domestic price stabilization. The food distributed freely is purchased by the government on the free market and is financed by reducing public investment.

The results of the runs are shown in Table 5 and are plotted in Fig. 3.

Between the base and the free food scenarios a fall in growth rate of real GDP of about 0.7% per year is observed. The increase in calorie consumption on the average is only marginal, as can be expected from the fact that total food availability has been more or less the same in the base and the free food scenarios. However, a major impact of the program is to be seen in the distribution of consumption as shown in Figs. 4 and 5, which show the number of people in rural areas in various income classes. The income classes are defined by income in base year (1970–71) rupees (see Table 6), and the two lowest classes do not have enough income to provide themselves with adequate calories and can be considered to be in absolute poverty. As can be seen in Fig. 5, under the free food program the number of people in absolute poverty drops to around 10 million in 1977 from its 1976 level of more than 160 million people in the rural areas. When we compare the two base scenarios of high and low growth, we see no change in poverty levels. So growth alone is not enough to reduce poverty. It is clear that such a free food program can be very

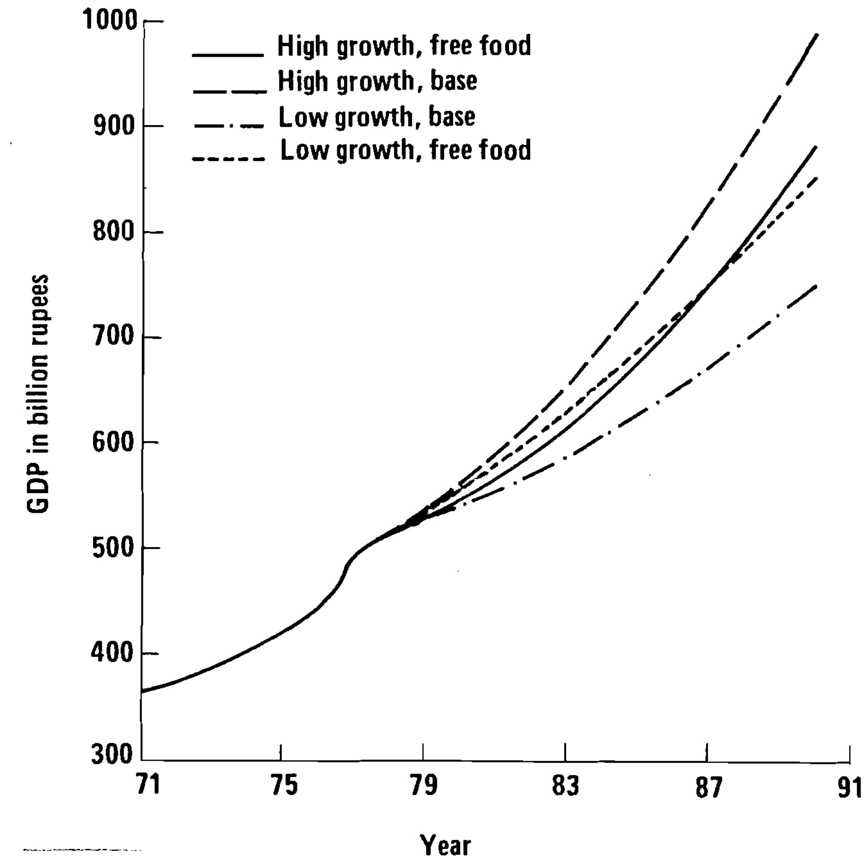

FIGURE 3 Real gross domestic product in India, 1971–91.

effective in reducing poverty. Its cost is lowered growth. A reduction of 0.8% in growth rate from the low and high growth base rates of 4.6 and 5.4 seems quite acceptable to us. But a reduction from an average annual growth rate of 3.5% as achieved by India over the past three decades may not be so obviously acceptable. The growth rates in our base cases are higher than actual because of our assumption of reduced capital/output ratios in the nonagriculture sector. Thus, if growth is stepped up, redistribution becomes easier but is still necessary to redress poverty.

We want to emphasize that this is merely an illustrative example. Many questions, even of this free food policy – its administrative feasibility, optimal level of distribution, etc. – still need to be explored, and further verification of these results is also required. The illustration is presented to show the scope of our model and to demonstrate the comprehensiveness with which it can be used to explore policy packages.

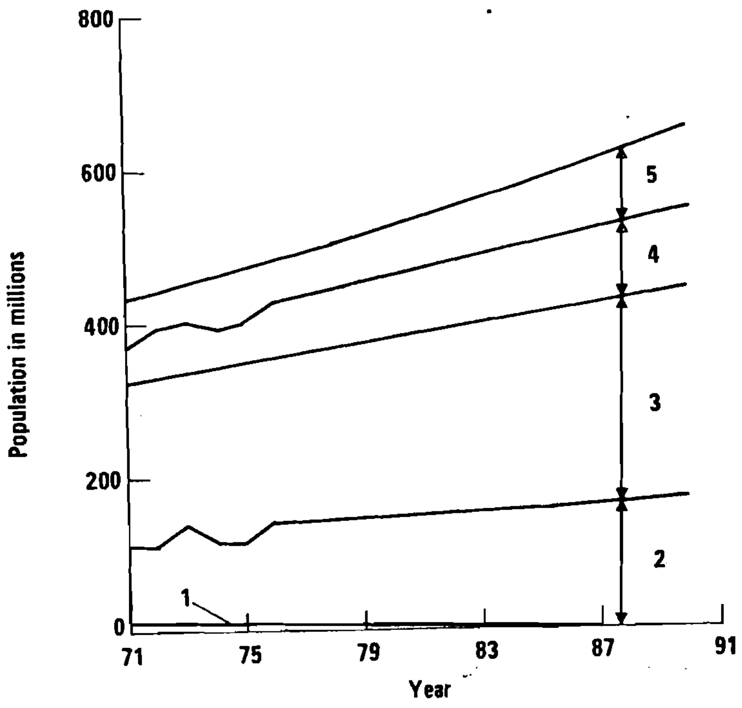

FIGURE 4 Rural income distribution – high growth base scenario.

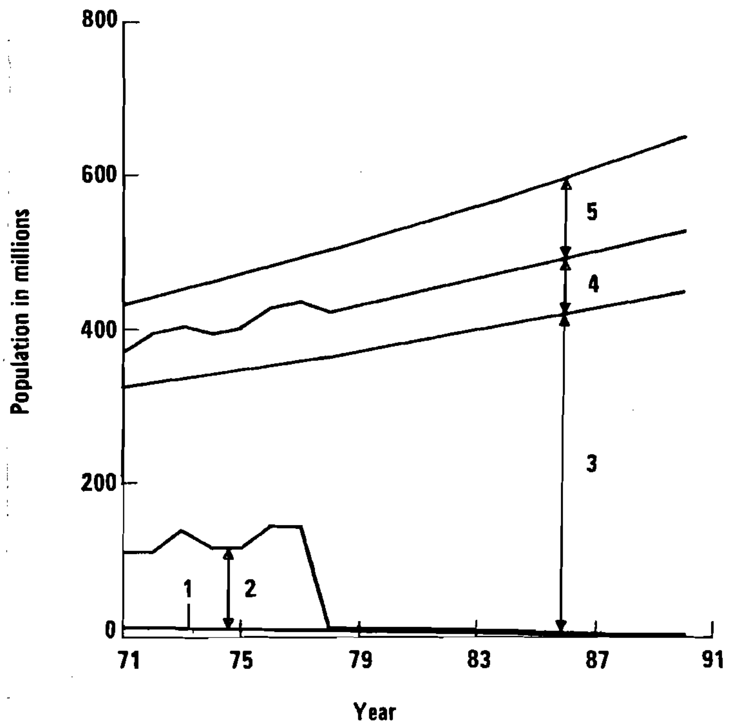

FIGURE 5 Rural income distribution – high growth free food scenario.

TABLE 6 Indian Agricultural Model results: calorie consumption by expenditure class.

	Expenditure class				
	1	2	3	4	5
Expenditure limits (rupees (1970) per person per year)	216	288	516	900	>900
Calorie* consumption (kcal per person per day)					
Rural 1980	1630	1980	2100	2450	4160
Urban 1980	730	1470	1570	1730	2910

*Average of scenarios.

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4.10. THE FINNISH FOOD AND AGRICULTURE MODEL

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4.10.1. The Purpose of the Model

The purpose of the Finnish food and agriculture model project is

- to determine the long-term problems of Finnish agriculture
- to build a mathematical model that can be used for the description of the development of agriculture and that includes policy factors that affect development
- to determine what kinds of policy action are needed to secure self-sufficiency in the long term.

The model reflects the present agricultural situation in Finland, which has such characteristics as small farm size, an excess of animal products, large annual variations in crop yields, the use of mainly imported energy in the agricultural sector, and generally slow economic development predicted for the future. Quantification of the various interrelationships in agriculture is an important but difficult part of the project. The final output should be a model which can be used for the simulation of agricultural development under different assumptions.

4.10.2. Some Features of the Structure of the Model

The Finnish food and agriculture model resembles in part the national models of the simplified system of IIASA, but in part it is different, owing to the emphasis of Finnish agricultural policy; for example, the supply model is built so that it can be used for studying the effects of the intensified supply control. Crop yields are dealt with separately in order to examine the effect on yields of the rise in fertilizer prices. The overall structural development of agriculture has also been given special attention in the model.

Agriculture is dealt with as a whole, and no regional or other classification is made. There is only one income group for the consumption model. The model is a pure simulation model; its overall structure is shown in Fig. 1.*

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4.10.2.1. Production

Many of the agricultural policy measures are aimed at curbing or even reducing the growth of production. This is the starting point for building the supply model.

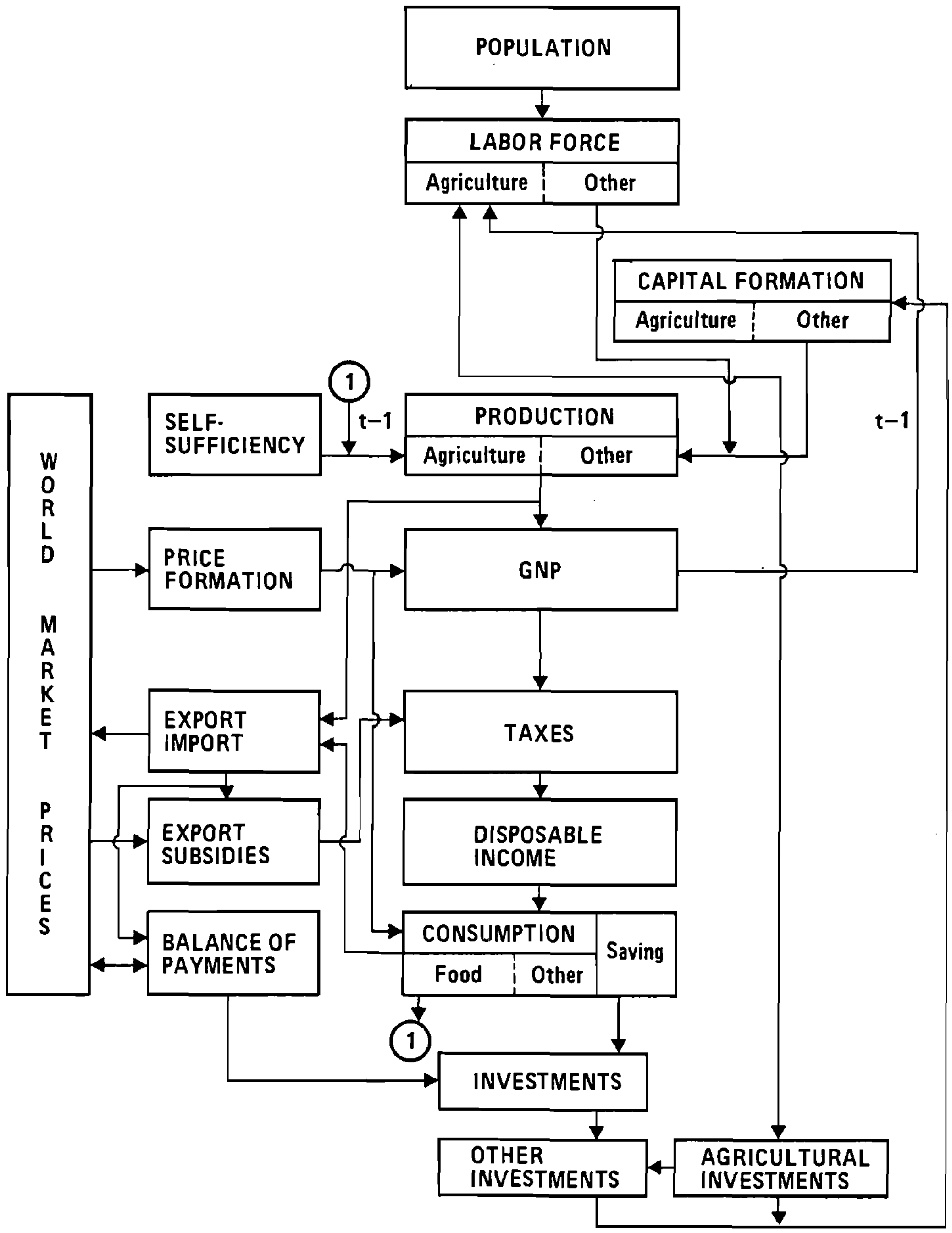

FIGURE 1 Finnish food and agriculture model (linkage).

Agricultural production is determined by ordinary supply functions. According to present practice, so-called production ceilings are set for the main agricultural products. If these ceilings are exceeded, farmers have to export the excess production at world market prices. For that

purpose marketing fees, which depend on the excess supply, are collected from agriculture. These lower the prices paid to farmers; this in turn reduces production through supply functions.

In the other version of the model, the only production targets are those determined by first setting self-sufficiency targets for each product. The development of consumption then regulates production. The purpose of this kind of approach is to study the need to draw land out of production in order to stabilize the demand and supply of agricultural products.

4.10.2.2. Yields

A parabolic function with the use of nitrogen fertilizers and the biological–technological development as an explanatory variable is applied to forecast the yields of plant products. The model solves first the optimum use of fertilizers, and this then determines the yield. The price of fertilizers is a scenario variable whose value can be changed.

4.10.2.3. Consumption

The linear expenditure system is applied to estimate the consumption of agricultural products. In addition, constant price and income elasticity models are also used. Both methods seem to give unsatisfactory results for the last years of long prediction periods (e.g., for 2000). (See Fig. 2.)

4.10.2.4. Structural development

The decision makers are concerned about the decline of the agricultural labor force and the depopulation of rural areas. It is even feared that this development may threaten self-sufficiency in agricultural production in the future.

The submodel of the agricultural structure is used to study the effects of declining agricultural population. The model generates the number and the average size of farms in different lines of production and in the whole agriculture system. In addition, the distribution of farms into different size classes is forecast by applying the log-normal distribution function.

4.10.3. The Application of the Model

The first version of the model is already running, although further work is needed to check the estimates of parameters and to elaborate some parts of the model.

In spite of the fact that the model is not yet fully developed, it has already been used for planning long-term agricultural policy. Demand for forecasts of yields, production, consumption, structural change, etc., is higher than the model can satisfy. The model builders are very much encouraged by the close following of the model building by decision makers. It seems the model will be in demand in the future, too.

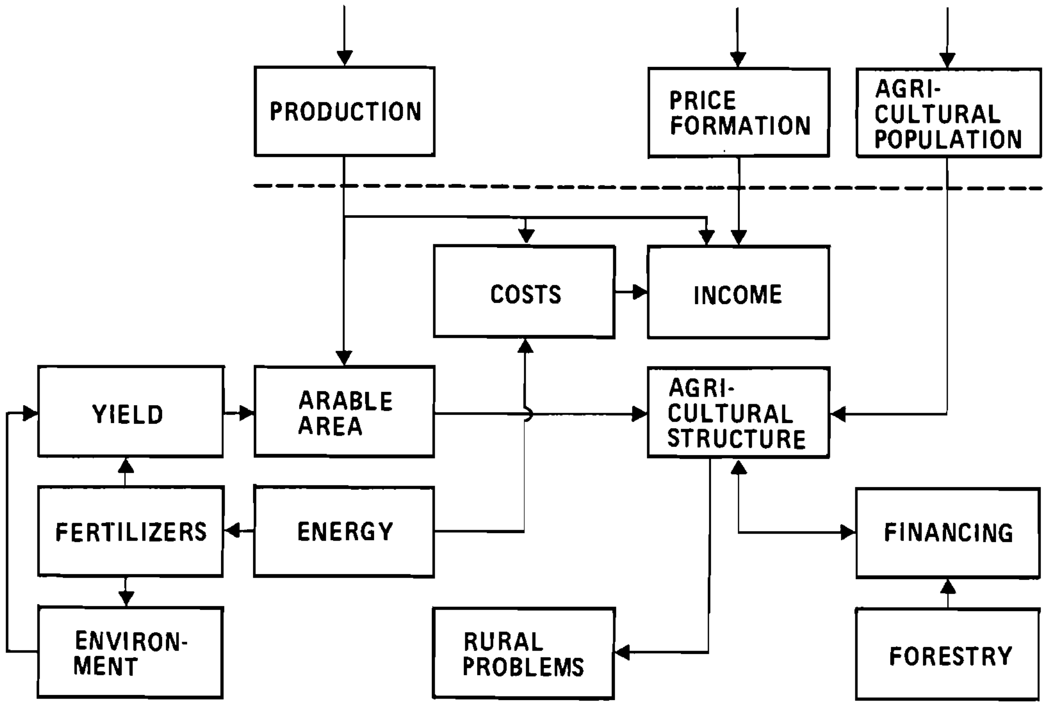

FIGURE 2. Agricultural submodel of the Finnish food and agriculture model.

It is hoped that the linkage of the Finnish model to the IIASA system will help in analyzing the effect of future world market prices on Finnish agriculture. Higher prices would give more room for policy makers in planning long-term production policy. However, Finnish model builders hope to get reliable forecasts from the IIASA model of agricultural production in the developing countries in order to be properly prepared to meet the possible need to increase food aid to developing countries.

4.11. THE SWEDISH FOOD AND AGRICULTURE MODEL

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4.11.1. General Modeling Framework

The Swedish food and agriculture model project is shown schematically in Fig. 1.

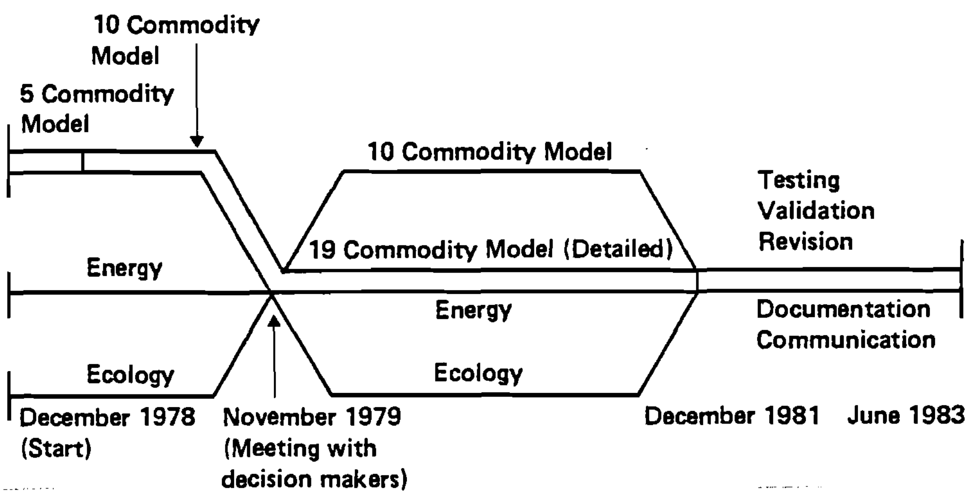

FIGURE 1 The scheme of the Swedish food and agriculture model.

The first year was devoted mainly to building simplified national models – first a five-commodity version and later a 10-commodity version. Some attempts were also made to identify problems of ecology and energy, to measure their importance, and to find methods for dealing with them.

Results are currently being presented to decision makers in order to have a good basis for specifying future work. From March 1981 the main effort will be directed toward building a detailed national model based on the 19-commodity list. Problems of ecology and energy will be confronted in this model. In addition, we plan to improve the 10-commodity simplified model to make it suitable for the basic linked system so as to be able to take part in the early global runs at IIASA.

The last year of project work will be used to communicate model results to decision makers as a way of validating the model and of making its results useful for a variety of purposes. In total, the resources in the project are 7.5 person-years, of which 3 person-years remain for 1981–1983.

The purpose of the work is to build a detailed simulation model of the Swedish agricultural sector in order to analyze the impact of various agricultural policies. We intend to construct a model that is positive, is based on econometrically estimated relations and is validated as much as possible.

We believe that there are ways of validating the model other than formal correspondence of the results produced by the model with historical observations. Therefore, we stress such aspects as descriptive realism, relevance, mode reproduction ability, insight generating capacity, fertility, ease of enrichment, transparency and simplicity.

The transparency aspect is important, since one of the main goals of the Swedish project is to establish and maintain contacts with decision makers and other groups and institutions in the field of agriculture so that the model can be constructed to answer the "right" questions. Up to now we have had several contacts with decision makers.

4.11.2. Results from Runs with the Simplified Model

The following scenarios have been run with the 10-commodity model and discussed with Swedish policy makers at their request:

- what milk price is needed to guarantee self-sufficiency in milk production?
- what are the consequences of free trade in agricultural products?
- what happens if use of fertilizer is sharply reduced?
- what happens if the price of protein feed rapidly increases?
- what are the consequences of an expanding biomass production for energy purposes on arable land?
- what are the consequences of a reduced rate of structural change in agriculture?

Exercises with the simplified model have been very important for justifying the modeling work to the policy makers and have also created a good basis for the ongoing work with the detailed model.

4.11.3. The Detailed Model

The general structure of the detailed model is shown in Fig. 2. The driving forces in production are prices derived from the exchange component. Production is then determined in two stages. In the first stage resources are set. In the second stage resources are allocated to products in plant and animal production. Variables such as the following act as restraints on behavior: stocks of land and capital, savings, weather, and the state of technology in two farm sectors – one consisting of part-time farms (small farms) and one of full-time farms (large farms).

Basic characteristics of the production model are:

- resource demand in plant production is derived from a capital–labor accelerator

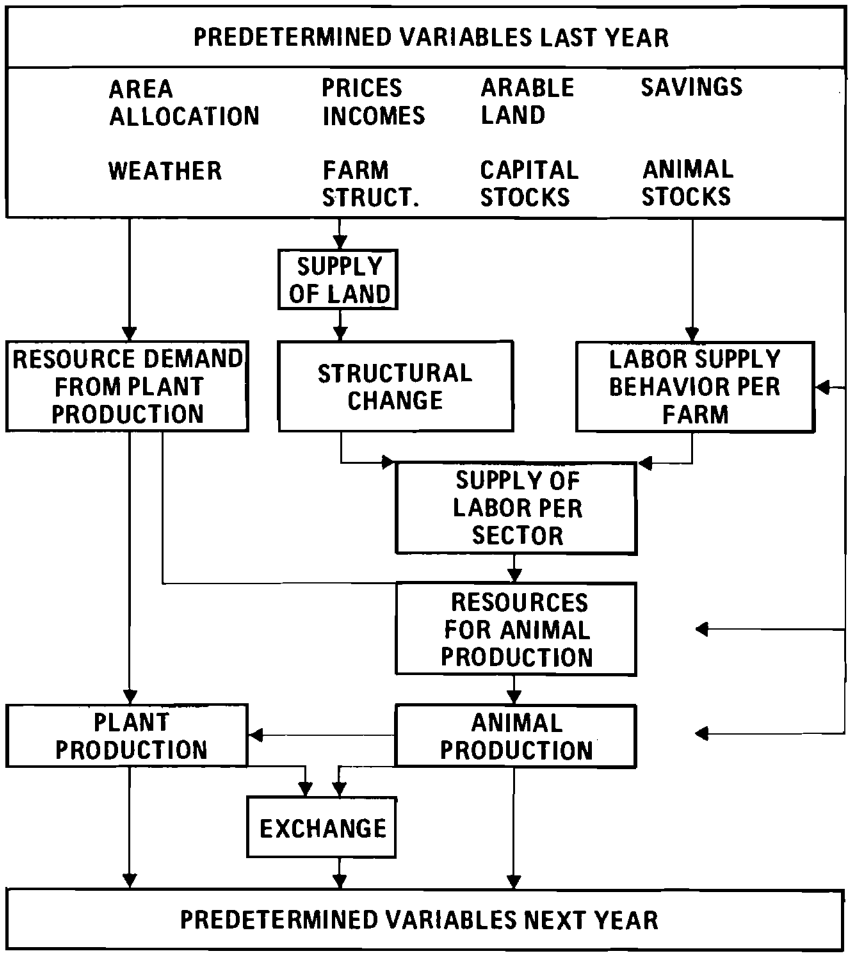

FIGURE 2 The detailed Swedish agricultural production model.

- substitution of roughage area for production of other crops is described by a Spillman function
- supply of farm labor is partly determined by farmers' "income demand"
- the rate of change in small farms is the driving force in structural change
- profitability orders resource distribution between plant and animal production
- production functions in the allocation models are expressed as follows: animal production – production functions per sector; plant production – production functions per hectare.

Production allocation models (two for each agricultural sector) are of a nonlinear optimizing type with econometrically estimated parameters.

A linear expenditure system is used to describe consumer behavior.

Agricultural policy will be modeled in detail, stressing official objectives of a fair standard of living for the agricultural population, increased efficiency in farming, the guarantee of a desirable degree of self-sufficiency, and the maintenance of reasonable consumer prices. If possible, we shall try to estimate previous behavior of policy makers as well as to introduce some additional policy measures according to nutritional and ecological considerations, as well as energy considerations. Policy measures should be endogenously determined in the model.

At the time of writing (March 1981), a technically operable version of the model is at hand. The project work is now concentrated on re-estimating the plant model and the demand functions. Furthermore, the policy model and energy-related activity have been planned in detail. These plans will be discussed with decision makers in April 1981.

4.12. MODEL DESCRIPTION AND APPLICATION: AUSTRIA

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4.12.1. Current State of the Modeling Effort

Work on an Austrian food and agriculture model started in mid-1979, when the Institute of Agricultural Economics (IAE) of the Federal Ministry of Agriculture and Forestry (FMAF) was invited to participate in the FAP of IIASA. The model has been developed in close cooperation with the group working on the EC models: the same methodology, much the same computer programs and data sources available at IIASA have been used for its construction and estimation. (See Section 2.2 of this report.)

As it stands now, the model has been thoroughly validated and is considered as a national version with certain capabilities. This reference model is designed to fit into the basic linked system of the FAP and to represent the system of agriculture and the Austrian economy in the detail required by the basic linked system. While work on a more detailed model is under way, the national model will serve as a means of analyzing policies and their outcomes, either as desired by clients or as a means of demonstrating the usefulness of our continuing modeling effort to the public and to decision makers in Austria.

4.12.2. Purpose of the Model

Agricultural policy addresses a set of objectives using various instruments. Any one of the instruments works toward certain objectives but affects others adversely. As time passes and this becomes apparent, the levels of instruments are adjusted to direct the agricultural economy toward the original or possibly even changed objectives. Problems perceived by policy makers are in those areas of the agricultural sector which are farthest from the desired state, and the level at which instruments are set is a function of the previous state of the sector relative to its desired state. The levels are decided on under uncertainty, since the outcome of setting instruments at a certain level is only tentatively known. The purpose of modeling the agricultural sector is to reduce that uncertainty by producing quantitative information over various years about how certain levels of instruments, or how a certain rule to adjust these levels, would affect the economy and its component parts.

The model will be operated by the IAE, in particular on behalf of the FMAF. It could be shared with other research institutions if they participated in its future development, which is open-ended.

4.12.3. Model Characteristics

The food and agriculture model for Austria in its basic linked system version disaggregates the economy into 10 sectors: nine agricultural sectors and one nonagricultural sector. It depicts the relationships between system variables in the following way. Occupational migration and the allocation of investments to the total agricultural and the nonagricultural sectors depend on past income and prices. Induced by a naive price expectation model, farmers allocate capital, labor and fertilizer simultaneously within agriculture, the objective being to maximize net returns subject to Cobb–Douglas production functions with embodied technical progress. Eight production processes are distinguished, yielding products and by-products that are then aggregated to conform to the original 10 sectors of the economy. These products go into feed, intermediate and/or human consumption. Only the latter is a variable for the exchange component of the model.

Exchange of goods is subject to government policies, desired prices, foreign trade quotas, buffer stock operations and the balance of trade. Domestic consumption depends on prices, a calorie intake target, and income, represented by a modified linear expenditure system. Equilibrium is achieved through adjustment of net exports, stocks and domestic prices in that order of priority.

The model is homogeneous of degree zero in prices and aims to trace the development of the national economy over a time span of five to 20 years. Policies are exogenous to the model and simulation runs are used to test alternative policies, which should be carefully defined. On the basis of these runs one can learn about policies and specify them more precisely to generate increasingly realistic outcomes.

4.12.4. Case Study: The Effects of Excess Milk Production

In order to demonstrate the capability of the national model for policy analysis, we chose the Austrian milk sector as a case study. The milk market is strictly regulated by the government because major social and economic policy objectives are involved: farm incomes can be boosted through producer price regulation for milk, farms in remote areas can be maintained and urbanization discouraged through transport cost compensation, the capacity of agriculture can be increased as marginal (mountainous) land stays in cultivation, domestic consumption of milk can be increased and a healthy diet promoted through price differentiation of retail dairy goods, and exports help to boost foreign exchange earnings.

Other effects of specific policies designed to produce a milk surplus can be detrimental. The model was used to determine quantitatively what difference it would make to Austrians if one of two alternative milk policies were to be selected. The two alternatives (base run, milk run) chosen for this case study differ in only one point. In the base run, the self-sufficiency in milk must not drop below 70%. If this occurs, producer prices are increased to keep production at 70% of consumption. In the "milk run," self-sufficiency in milk must be at least 120% in 1977 and in subsequent years, again achieved by varying producer prices.

Neither of the alternative runs is meant to represent actual developments after 1976, when prices changed in favor of nonagriculture, off-farm migration decreased substantially because of a recession, milk production increased and farm quotas for milk were introduced which reduced self-sufficiency in milk to about 110% of domestic consumption (including feed).

Some of our results are presented in Table 1. They show that a substantial increase in the price of milk is necessary to keep production at the 120% level. Otherwise self-sufficiency quickly drops to the lower bound of 70%, as labor moves out of agriculture into more profitable employment. In the milk run, higher milk production draws resources away from the production of other agricultural commodities, causing some of their prices to rise so that a minimum required self-sufficiency level of these commodities can be maintained. At higher price levels, human consumption of milk decreases just slightly. Since milk and beef are treated as joint products in the model, similar results hold for both milk and beef commodities. With higher output and more labor employed in agriculture, the milk run produced an additional 3 billion Austrian Schillings (AS) (200 million US $) of gross domestic product (GDP) in agriculture in 1990 (using 1970 commodity prices) and a more even distribution of income between agricultural and nonagricultural labor. Occupational migration virtually came to a standstill after 1980, whereas agricultural labor decreased by almost a quarter during the following decade in the base run.

TABLE 1. Selected results of the simulation for Austria.

	Year	Base run	Milk run
Milk			
Producer price	1976	2.98	3.27
(AS/kg)	1985	3.33	4.82
	1990	3.71	5.06
Production[a]	1976	2990	3170
(1000 tonnes)	1985	2480	3570
	1990	2550	3760
Coarse grains	1976	2740	2570
Production[a]	1985	4130	3650
(1000 tonnes)	1990	4970	4730
Labor in agriculture	1976	333	333
and forestry	1985	223	281
(1000 persons)	1990	213	286
Gross domestic product			
Agriculture	1976	18.5	18.5
(billion AS)[b]	1985	18.9	20.8
	1990	20.9	23.9
Total	1976	483	483
(billion AS)[b]	1985	648	641
	1990	718	706

[a]Less seed and waste.
[b]At 1970 prices.

The cost of excess milk production to society is reflected in the GDP that could have been realized had labor been employed more efficiently.

This amounts to almost 12 billion AS (800 million US $) in 1990 when using commodity prices of 1970. On top of that, the inventory of capital is less than in the base run and food prices are higher, demanding a greater fraction of income from consumers. However, a final evaluation of the alternative policies cannot be based on these figures alone, but the externalities mentioned must be taken into account.

4.12.5. Further Research

The national (basic linked) model appears to be a useful tool for policy analyses within certain limits, which are given by the variables used to describe the agricultural sector (i.e. the commodity classification) and the type of the relationships hypothesized between them. The parameters of the model are based on observed data for the period 1962 through 1976; this also imposes limits on the analyses of specific policies.

We now intend to proceed in two directions. In the first we shall communicate the national model and some of its findings to the scientific community and possible clients with the aim of stimulating a dialogue with them. It is hoped that this will direct the development of a more detailed model and generate a broader-based participation in related research.

Second, we are working on the development of increasingly detailed models of the Austrian economy. This work should provide a tool which can be used both to analyze the impact of domestic and foreign trade policies on domestic markets and to produce information which is relevant for decisions to be taken by members of the FMAF.

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4.13. AN AGRICULTURAL POLICY MODEL FOR JAPAN

4.13.1. Introduction and Organizational Affiliation

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University of Tsukuba, Japan

The Japanese policy model for food and agriculture has been studied by a team of seven scientists – five from the University of Tsukuba and two others from associated universities near Tsukuba – under the chairmanship of the present author. For the past several years the research activities of this team have received their main financial support from the University of Tsukuba, the Japanese Ministry of Agriculture, Forestry, and Fishery, and the Japan Committee for IIASA. The research activities of this team have covered three rather distinct lines of effort: developing the Japanese Agricultural Model (JAM), the "food security program" for Japan, and the associated data banks. A brief account of these efforts and of some accomplishments is given in this paper.

4.13.1.1. The Japanese Agricultural Model (JAM)

The underlying philosophy of JAM has been developed by the present author (Maruyama, 1980) and has been elaborated into a mathematical framework by Onishi (1980a). It is composed of eight modules, as are similar models for the market economy countries. Fish and rice constitute the most important elements of the Japanese diet, as they do in JAM. Research on the consumption demand module has been undertaken by Sasaki, and considerable progress has been made. Major accomplishments made by Sasaki were reported in the Status Report Conference (Sasaki, 1981). In connection with this research he has developed an efficient computer program for estimating the dynamic linear expenditure system.

Research on the agricultural production and international trade modules has been carried out by Kuroda. Some of the results he has obtained in this connection have been published in academic journals of international circulation (Kuroda et al., 1979, Kuroda and Yoshida, 1981; and others). Research on the government policy module has been undertaken by Onishi, and some tentative results were reported in his paper "A Policy-Oriented Rice Economy Model of Japan" on the occasion of the Status Report Conference. He has also developed a computer program for estimating and simulating a large-scale simultaneous equations system (Onishi, 1980b and 1980c).

4.13.1.2. The food security programming model

The Japanese nation imports more than 60% of its calorie intake from other nations. It is therefore natural for Japan to become very conscious of the security of its food supply, which is liable to be jeopardized by international incidents or by unfavorable weather outside Japanese territory. This is why the Japanese Ministry of Agriculture, Forestry, and Fishery wants to develop a "food security programming model" similar to the one developed in Switzerland (Onigkeit, 1976). The ministry could thereby obtain necessary insight into the problem Japan faces with its nutritional requirements, production and import possibilities, and so on, in order to design several effective policy measures to enhance security in these matters.

Since endowments of arable land and other productive resources are far more meager per capita in Japan than in Switzerland, Japanese model builders are understandably much harder pressed than their Swiss counterparts. The building and analysis of the model are taken charge of by the present author (Maruyama, 1981). The model includes nearly 500 variables and 400 logical equations. It may conveniently be divided into four interdependent submodels: production, consumption, import, and stockpile. The production submodel incorporates crop production, processing, feed production and animal production.

The performance of the model has been examined with regard to the aggregate supplies of calories, protein, fat and oil, and animal protein, and to the required variety in diet available to the nation. The preliminary results confirm Japan's vulnerability in major agricultural imports, e.g. wheat, corn, soy beans, and vegetable oil. They also suggest that the stockpile necessary for assuring 2250 calories per capita per diem and requiring less than 15% variety in diet does not amount to very much: nearly 70 days of standard supply except in the case of extreme emergencies.

4.13.1.3. Data bank

A data bank containing nearly 700 series of macroeconomic indices and individual items of the food balance sheet, agricultural inputs, capital stocks, imports and exports, and the associated prices for individual years from 1955 to 1978 is being purchased from a commercial supplier. The purchase is being financed by the University of Tsukuba. Other necessary items are being produced by the staff at the University.

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4.13.2. Estimation of the Consumer Demand System in Postwar Japan (Summary)

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This report presents a method of food demand analysis and its application to Japanese expenditure data from 1951 to 1977. The method adopted is the linear expenditure system developed by Powell, which is effective in analyzing a number of commodities under the additive preference assumption. It was fitted to the time series of family budget data, deriving the consumer demand system on a per capita basis. The total expenditure was divided into 24 groups of commodities, with 11 subgroups of food commodities and 13 subgroups of nonfood commodities. Food commodities are classified as rice, other cereals, fish, meat, milk and eggs, vegetables, processed food, cakes, fruits, beverages, and food consumed away from home.

First, a linear approximation by the static linear expenditure system is conducted to proper segments of the entire period, considering marked changes in consumer demand for the past three decades. Estimated parameters of the demand model yield estimates of income and price elasticities of demand, money flexibility, subsistence consumption levels, etc. Second, taste variables are introduced into the demand system in order to make it dynamic. The dynamic model was fitted to longer time series of per capita expenditure and price data, with two alternative specifications of the proxy for the taste variable. One is an annual increase in total expenditure, and the other is an annual rate of increase in total expenditure. In the dynamic model, the cost of living index and the subsistence cost are obtained in addition to the estimates of some important demand and utility parameters mentioned in the static model.

The static model yielded well-defined demand relations and their characteristics in various subperiods, particularly in the three subperiods 1951–60, 1961–70, and 1963–77. Such a static approximation was attempted to preserve the linearity of expenditure functions and to take account of the changes in preferences. Evidently from the empirical results, price and income elasticities of demand have changed over time, and the values of money flexibility show a little variation depending on sample period, commodity classification, and so on.

In the dynamic model, the estimated parameters for the taste variable were not adequate, but many important demand and utility parameters were obtained. Estimates of money flexibility were smaller in absolute terms than those of the static model, implying that own price elasticities in the dynamic model appear greater than in the static model. Estimated parameters were rather stable on the whole.

In any case, the goodness of fit of the models in the interpolation test is very high.

4.14. THE THAILAND AGRICULTURAL MODEL: A POLICY MODEL FOR AGRICULTURE

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4.14.1. Introduction

In order to analyze policy problems of the Thai economy, a dynamic simulation model has been designed which describes supply, demand, income, and price formation. This paper gives a concise description of the model. In addition, some results are discussed. An extensive description of the model structure as well as a detailed description of the data base can be found elsewhere (Centre for World Food Studies, 1980 a–d).

4.14.2. THAM-1 as a Linkable Model

THAM-1 is a member of the IIASA group of national models for food and agriculture, and as such it satisfies the requirements for linkability into the general equilibrium model of international trade. These requirements can be summarized as follows.

(a) Net import orientation. At given levels of international prices and national trade deficits, each national model generates, on a yearly basis, net imports which follow a commodity breakdown that fully covers the real sector in the economy and is common to all nations.

(b) Monetary neutrality. Money is only considered as a unit of account and not as a commodity. Changes in the money supply do not affect the quantities supplied and demanded.

(c) Lagged supply. Price and income formation in the current year only affect supply in the following year(s).

4.14.3. Main Structure of THAM-1

The model distinguishes actors at the national and at the regional level. At the national level, *government* influences the international conditions of the economy through the regulation of income, excise tax, public demand, tariffs, and quotas on net imports. Within each region, *income groups* (farmers and nonfarmers) supply and demand commodities at ruling prices. Given one year's price realization, resource levels (land, labor, capital) are adjusted, and the next year's supply is planned through a regional linear program. Supply is then distributed over income groups on the basis of resource ownership and marketed in the next period. Commodities are processed into final product and used for consumption or investment purposes by income groups or government. The excess demand must be imported, but may not exceed its bounds (quotas). Given the trade deficit this can be realized through the adjustment of excise tax, retail price and public demand.

Figure 1 is a schematic representation of the model. It shows the lagged supply (through the lag operator E^{-1}), the simultaneous nature of demand, price and income formation, and the hierarchy between international, national and regional levels.

4.14.4. Country-Specific Characteristics

THAM-1 distinguishes itself from other national models within the FAP through its emphasis on regionalization, income disparities, and the use of agronomic information in describing agricultural supply behavior.

(a) Regionalization. Six agricultural and one nonagricultural region (Bangkok), embedded in five main regions, are distinguished. This makes it possible to allow for differences in geographical as well as economic conditions between regions and to introduce interregional migration.

(b) Income disparities. The agricultural sector in each region is subdivided into three farm size groups. Resource accumulation is generated at farm group level so that an endogenous income distribution can be represented. Within the nonfarm sector, three income groups are distinguished with a fixed share in the sector's income.

(c) Agricultural supply module. For the representation of the agricultural sector as much use as possible was made of technical data available either from technical microstudies or from soil maps and climatological data. A general physical crop model was designed in order to generate data on potential crop yields, natural fertility, and land availability in each region. The basic assumption underlying the physical crop model is that the factors that determine crop yields can be ordered into *hierarchical groupings*. Also within these groupings, hierarchies are established, and at each level submodels are developed which are sequentially linked. The hierarchical sequence consists of the following main components: solar energy, temperature, available water, and available plant nutrients. The data generated by the physical crop model serve as parameters in the regional linear programs. Some characteristics of these linear programs are as follows:

   - a monthly account is kept of all labor and power requirements
   - an interdependence between crop and livestock sectors is depicted through manure and draft power requirements for crops, and feed requirements for livestock
   - the subsistence production is explicitly represented in the linear programs by introducing consumer demand functions as constraints

4.14.5. Results

A number of runs have been carried out with THAM-1. The results of some of them will be discussed in this section.

Figure 2 shows price projections for rice, sugar, coarse grains, and nonagricultural product (central run). The price projections are based on the world market prices in the period 1960–1978 adjusted to the tariffs raised by the Thai government during that period. For the period 1980–1989 an alternative price projection for rice has been made in

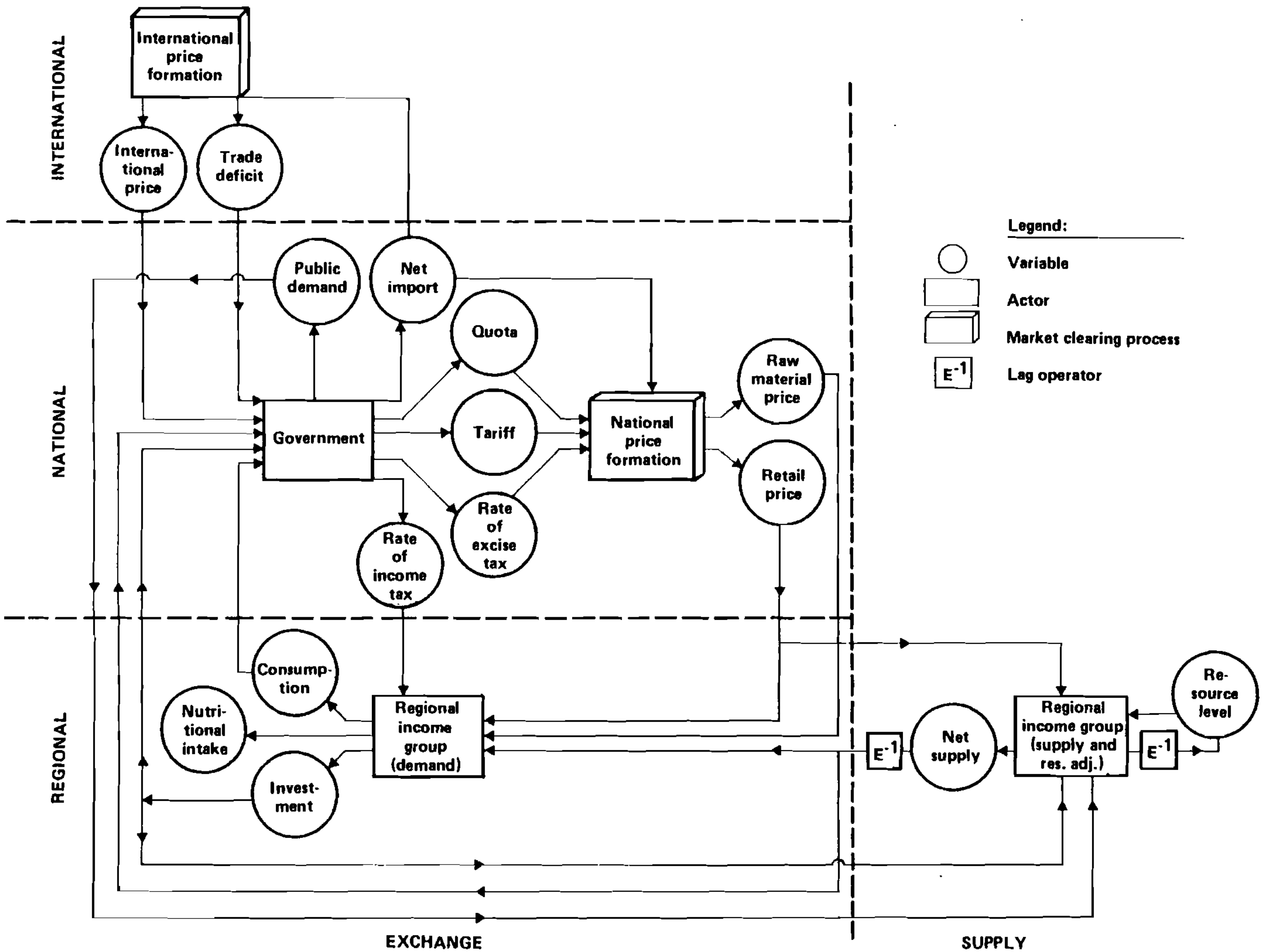

FIGURE 1 Schematic representation of the Thailand agricultural model.

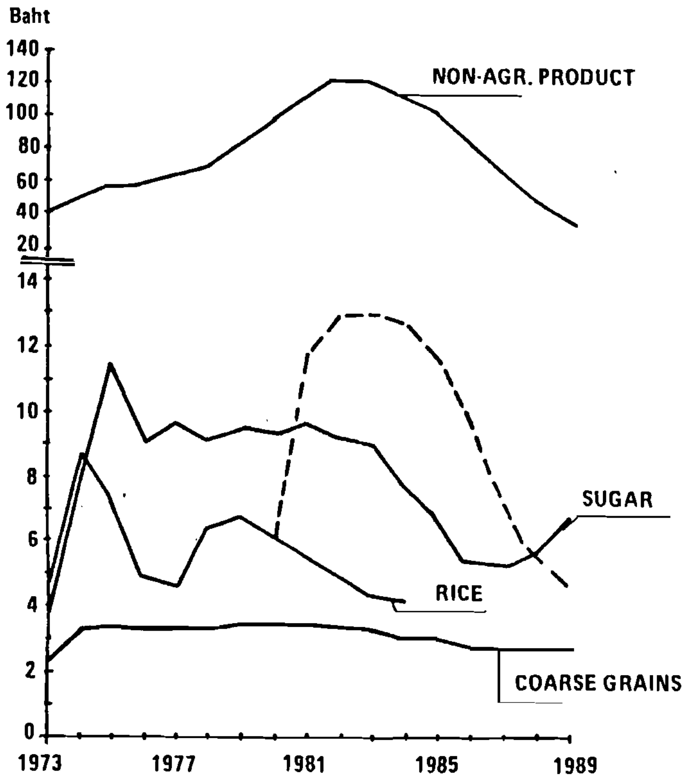

FIGURE 2 Market prices for rice, coarse grains, sugar, and nonagricultural products in Thailand.

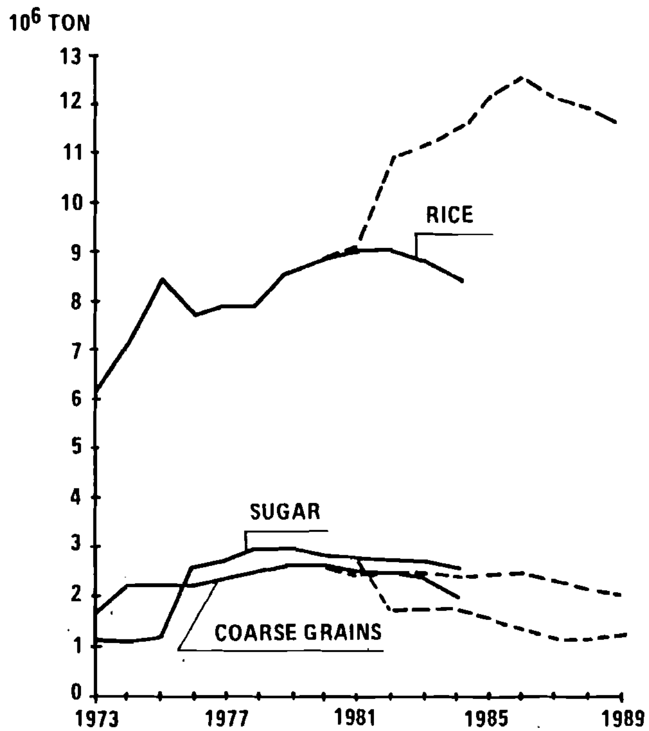

FIGURE 3 Rice, coarse grains, and sugar production in Thailand.

which the rice/nonagricultural product price ratio is kept constant at the rather high level of 1973. In the model this is done by intervention of the government on the rice market. In the diagram this is indicated by the dotted line (alternative run). If we look at the production figures of the central run (the solid lines in Fig. 3), we see an increase in rice, sugar, and coarse grain production in the mid-seventies. Production figures stabilize during the late seventies, and in the early eighties they go down slightly. In the alternative run, that is the run with the relatively high rice price, a different picture emerges (dotted lines, Fig. 3). Rice production increases rapidly, while sugar production falls. For coarse grains a slight improvement takes place in the early eighties. After that production stays rather stable. The decrease in sugar production reflects the competition that exists between rice and sugar for irrigated land. The slight improvement in coarse grain production is caused by the higher input use as a consequence of higher incomes.

Figure 4 shows net export figures. Trends for different crops are identical to trends in production: a rise in the early seventies and a small decrease in the early eighties. The alternative run (dotted lines) shows a rapid growth in export for rice to nearly 5 million tons in 1986, and a fall in sugar exports. According to this run, in the second half of this decade Thailand even becomes an importer of sugar.

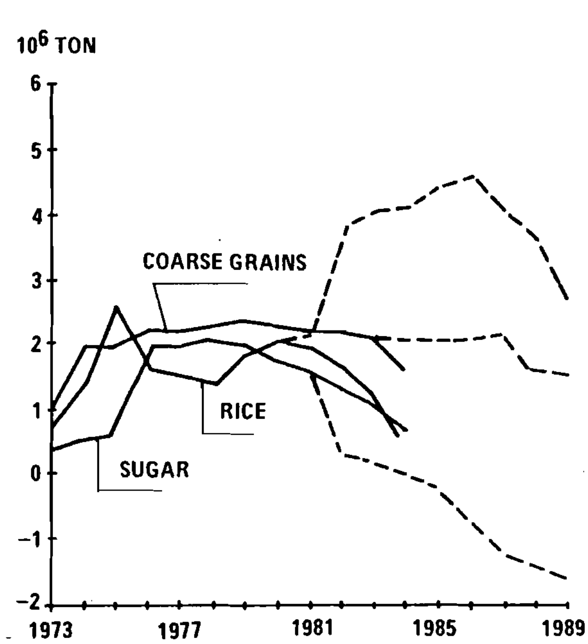

FIGURE 4 Net exports of rice, coarse grains, and sugar from Thailand.

It is interesting to look at the corresponding income figures for the different farm groups. Figure 5 gives these figures for the northeastern region. The central run (solid lines) predicts for the large, the medium, and the small farms a deterioration in real income. According to this run, income differences become smaller. A more optimistic picture for the Thai farmers emerges if rice prices are kept at a high level. A sharp rise

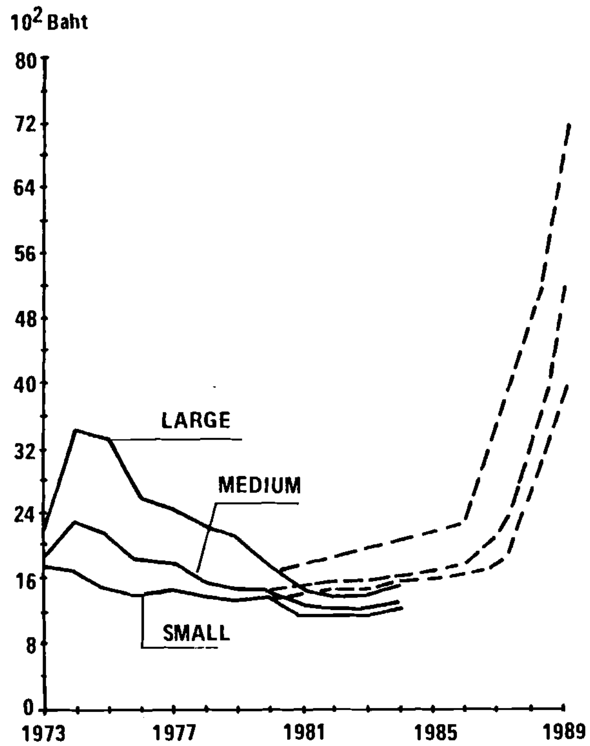

FIGURE 5 Per capita incomes for small, medium, and large farms in northeast Thailand.

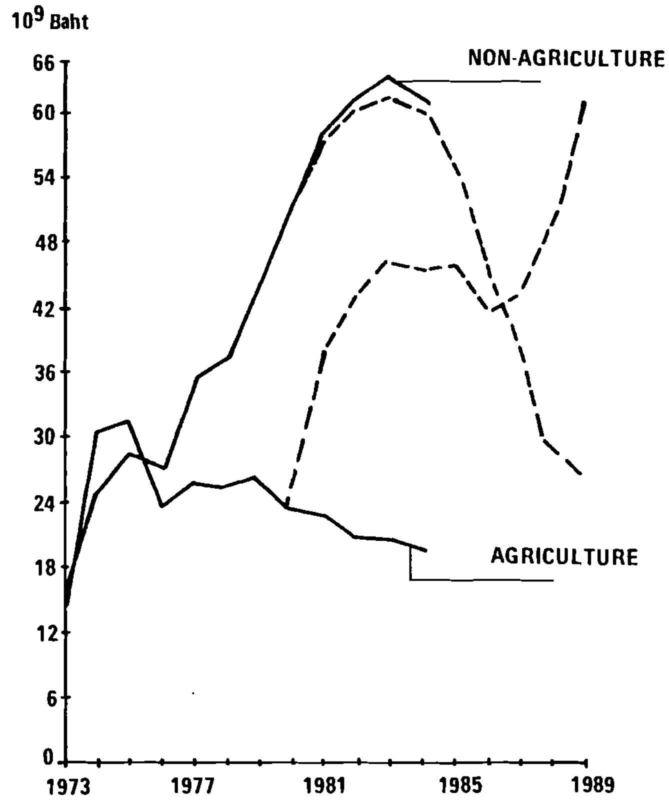

FIGURE 6 Income distribution for agriculture and nonagriculture in northern Thailand.

in real incomes is the result, especially in the second half of the eighties. The differences in incomes between the three farm groups, however, become greater.

Another way of looking at income distribution is to compare total income in the agricultural sector with total income in the nonagricultural sector. This has been done for the northern region in Fig. 6. As can be seen, the central run shows a rapid increase in total income in the nonagricultural sector, while total income in agriculture stays roughly at the same level. The alternative run shows an opposite development. From 1987 on, total agricultural income is even higher than total income in the nonagricultural sector. This is partly caused by the high transfer of income from the nonagricultural sector to the agricultural sector as a consequence of the government policy of keeping the rice price at a high level.

Figures 7, 8, and 9 give alternative production, trade, and income projections for the period 1980–89. In one of the projections, the so-called high rice price projection, it is assumed that the government keeps the rice/nonagricultural product price ratio at the level of 1973, and in the other projection it is assumed that the international price for the nonagricultural product is 5% higher than was projected in the central run. The consequences of these price changes are quite impressive. The run with the high rice prices shows a growth in production, while in the run in which the price of the nonagricultural product is assumed to be high, a sharp fall in rice production takes place (Fig. 7). According to that run, Thailand even becomes a large importer of rice in the second half of the eighties.

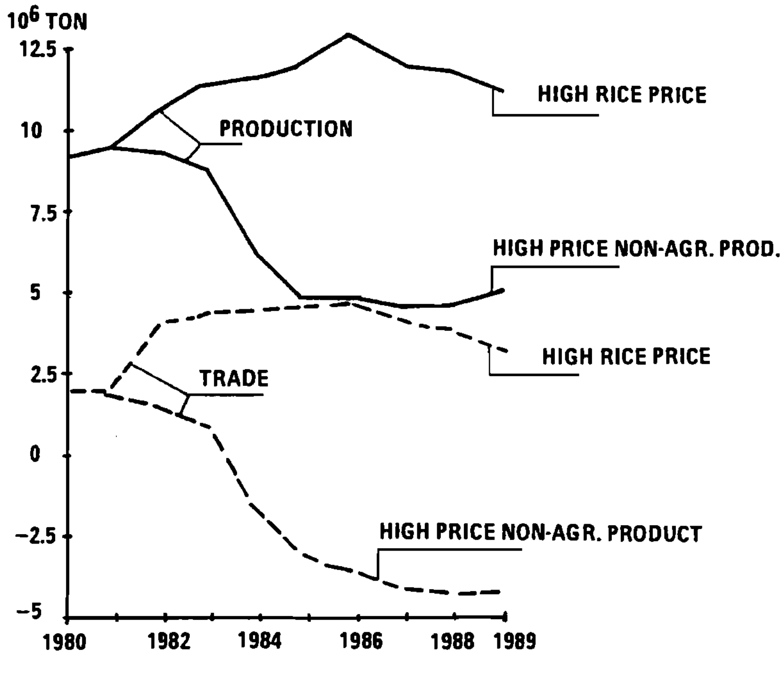

FIGURE 7 Rice production and trade in Thailand.

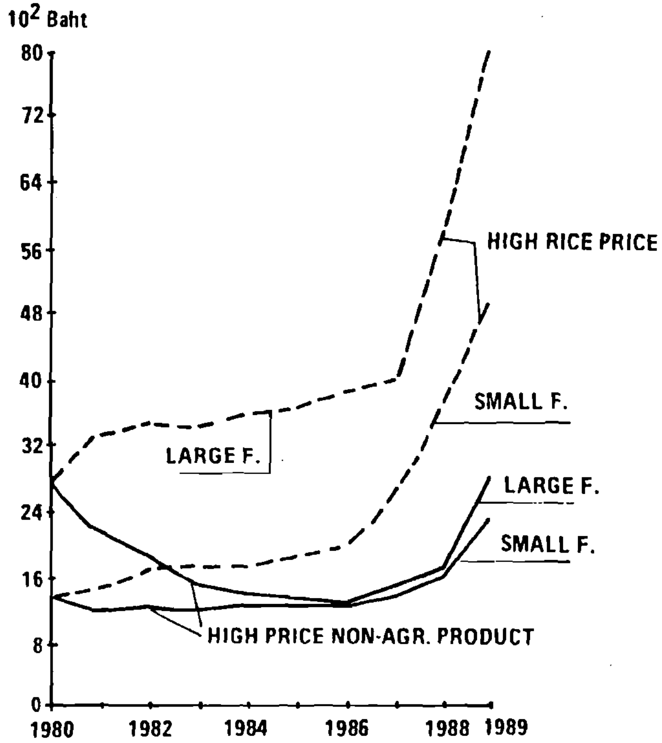

FIGURE 8 Per capita income for small and large farms in lower northern Thailand.

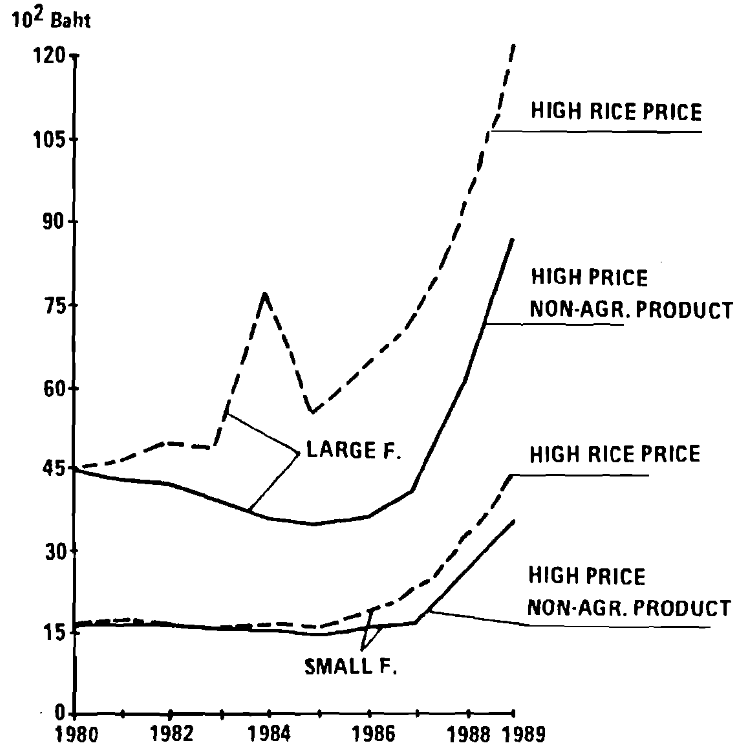

FIGURE 9 Per capita income for small and large farms in southern Thailand.

These alternative price projections also have important consequences for the per capita incomes (Fig. 8). In the run with the price for the nonagricultural product 5% higher than that projected in the central run, real incomes for the large farms in the lower north fall in the first half of the eighties, while those for the small farms stay more or less at the same level. The latter is a reflection of the fact that the small farms are less market oriented. If the price of rice is kept high, however, incomes for both groups improve rapidly. Not only is more land allocated to rice production, but also more fertilizer is used.

As can be seen in Fig. 9, differences in income development according to the two projections are much less pronounced in the south. This is because in the south rubber, instead of rice, is the main product. Thus a high rice price affects the farmers much less. However, within the IIASA commodity classification rubber is treated in the exchange component as a nonagricultural product, so that the influence of a high price for the nonagricultural product is felt quite differently in the south and in the north.

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PART 5. TECHNOLOGICAL TRANSFORMATIONS IN AGRICULTURE: RESOURCE LIMITATIONS AND ENVIRONMENTAL CONSEQUENCES

5.1. TECHNOLOGY TRANSFORMATIONS IN AGRICULTURE

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In 1980 the study of the longer-term problem of technological transformation was formulated as a second task of the Food and Agriculture Program. The reasons and considerations which led to this formulation have already been explained in Part 1 by Parikh and Rabár. The crucial role of technological change has been stressed in coping with the problem of meeting global food requirements, while at the same time keeping the development of the agricultural system sustainable in the long term, and considering the resource limitations and possible environmental consequences of various alternative paths of technological development. Within the scope of work on this very complex problem the following questions have to be investigated.

- What are the alternative technologies likely to be available within the next 20 years and beyond?
- What would be the appropriate combinations of these technologies in a given region (country) under various scenarios for resource availability and food demand?
- What sustainable potential production can be achieved with the given resources, with the available technological alternatives, and considering the possible environmental consequences in a region, in a country, and at a global level?

It was realized that a level of detail would be needed sufficient to express environmental aspects with relevance to particular natural resource characteristics, and to describe technological aspects in various ways. Work was begun on the development of a general methodology and a system of modules which could be used to generate alternative paths of development of the agriculture systems on the regional level and over a long time horizon of 20 or more years.

Considering the great variety of economic and natural resource conditions in individual regions within countries, it is obvious that the afore-mentioned methodology is suitable for application in a few of these regions within the scope of our project. The case studies undertaken by us should serve to validate our approach and should help in analyzing the appropriate technological development in various types of agriculture systems.

For this reason work was started along several lines, namely:

- setting up a general methodological framework
- articulation of individual modules of the system
- making a number of case studies
- assessment of traditional and nontraditional technologies.

5.1.1. The General Model Structure

In establishing a general methodology, four principal modules were defined within the model structure, each having a specific role and its own internal structure. Figure 1 shows the proposed general model structure in a highly aggregated way. It also shows the recursive character of the system; the function of each of the elements is repeated for each period of time (year) after the data base has been updated based on results of the previous period.

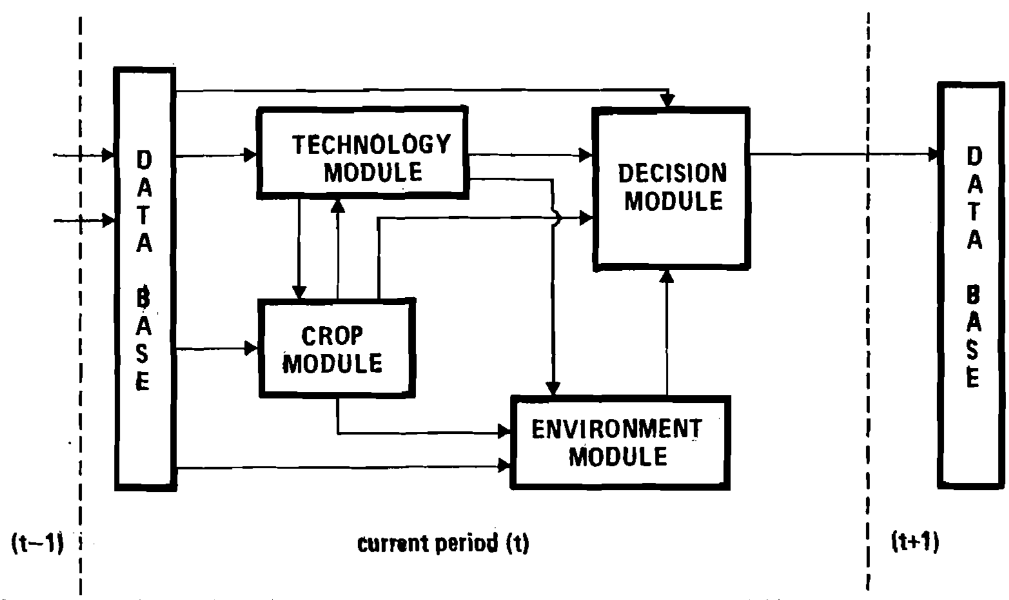

FIGURE 1 General model structure.

The arrows indicate the flow of information between the various elements of the system and thus the sequence of computation. Some connections are oversimplified here owing to the high level of aggregation. Further details will be discussed in Sections 5.2, 5.3, and 5.4. In principle, the crop, technology and environment modules generate a relevant subset of alternative techniques available for the production of a certain commodity at different chosen levels of detail, given the natural resource base, and alternative input (fertilizers, water) levels. In this way, possible alternative yield levels can be considered. The optimal production structure and appropriate mix of technologies are selected in the decision module from amongst the alternatives described by a set of yield, input and environmental coefficients, taking into account the given constraints. Once the production structure has been realized, the impact of technologies used on natural resources (environment module) and economic conditions can be estimated (updating for the next period).

5.1.2. Case Studies

Work on several case studies has recently begun. The selected regions are of different size, differ in natural resource conditions and also represent agricultural regions in various socioeconomic conditions. Owing to limited financial resources, work has presently been started in five regions, as shown in Table 1.

TABLE 1 Case studies of technology transformation.

Country in case study	Scope of study
Hungary	Country by regions
Kenya	Country by regions
US	State (Iowa) by regions
USSR	Region (Stavropol)
Czechoslovakia	District (Nitra)

The case studies cover the regions defined within the country; and in two cases (Hungary, Kenya) it is planned to cover all regions and thus the nation. In the Iowa case study the interaction between the region/state and the national level has also been considered.

Stages of work in some cases could be speeded up considerably using the experience gained from projects already in existence, as can be seen from the case study reports that follow.

The interest shown by various countries in analyzing the problems defined by Task 2 indicates the possible extension of the number of case studies carried out at a later date. Preparatory work has already been initiated for regions in Japan, Italy, Bulgaria, and the German Democratic Republic.

5.1.3. Technology Review

An important part of the task's structure is the review of technologies presently available and that will be available during the next 20 years. This review should include:

- technologies widely used at present in food production (traditional technologies)
- technologies likely to be available during the next 20 years, using the same kinds of key inputs and giving traditional types of products (nontraditional technologies)
- nontraditional technologies, which are or will be available for the production of food, feed or bioenergy from nontraditional sources

The ultimate goals of the task's activities in the latter field are:

- to review present knowledge on the development and use of such technologies
- to assess the relative importance of these technologies and their possible impact on the food situation both in particular regions and on the global level
- to analyze the factors influencing the implementation of these technologies

In order to initiate this research work, a task force meeting was held at IIASA on 23–24 September 1980 as a followup to previous collaboration and preparatory work jointly carried out with the Department of Food Science and Technology, Tbilisi State University, USSR, and the National College of Food Technology, University of Reading, UK.

5.2. THE TECHNOLOGY MODULE

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The roles of the technology module within the overall structure of the system are as follows.

- To generate all the relevant alternative technologies for the production of different products. This is done in two steps.
  - In Step 1, all the combinations of alternative operations necessary in order to produce the desired product are generated. These combinations are not dependent on yield levels. By generating the set of alternative technologies in this way, technical feasibility of alternatives can be ensured and infeasible combinations excluded.
  - In Step 2 the alternative technologies generated in Step 1 are modified according to the given alternative yield levels, alternative input (water, fertilizer) levels relevant to the yield levels, and land classes (soil types) for crop production technologies taking into account the soil-related or yield-related character of individual operations.
- To update parameters describing the operations according to technological progress which may take place over a period of time.
- To prepare data files both for the decision module and for the generation of environmental coefficients (environment module).

In order to reflect the technological changes and alternatives of the various parts of the production process, operations are defined as individual parts of that process. Figure 1 shows an (aggregated) example of this structure.

As one part of the overall model structure, as shown in Fig. 2, the technology module is interconnected to the crop module and the environment module. It is necessary to consider the following factors within this interconnection:

- the effects of applied and alternative techniques on the maintenance and the improvement of soil fertility
- the criteria for choosing techniques taking into account given natural conditions (soil in particular)
- short- or long-term impacts of applied or projected techniques on the environment and the resulting requirements on the orientation of technological processes

Figure 3 gives a general overview of the proposed structure of the operation sets for crop production technologies. One operation set is described by the data on the activities producing a defined unit of outputs

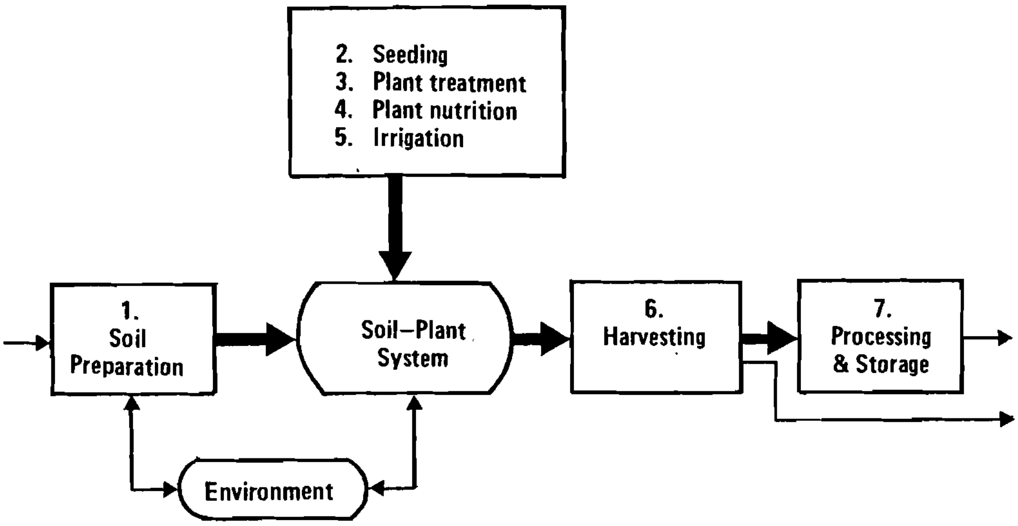

FIGURE 1 The overall structure of plant production technology.

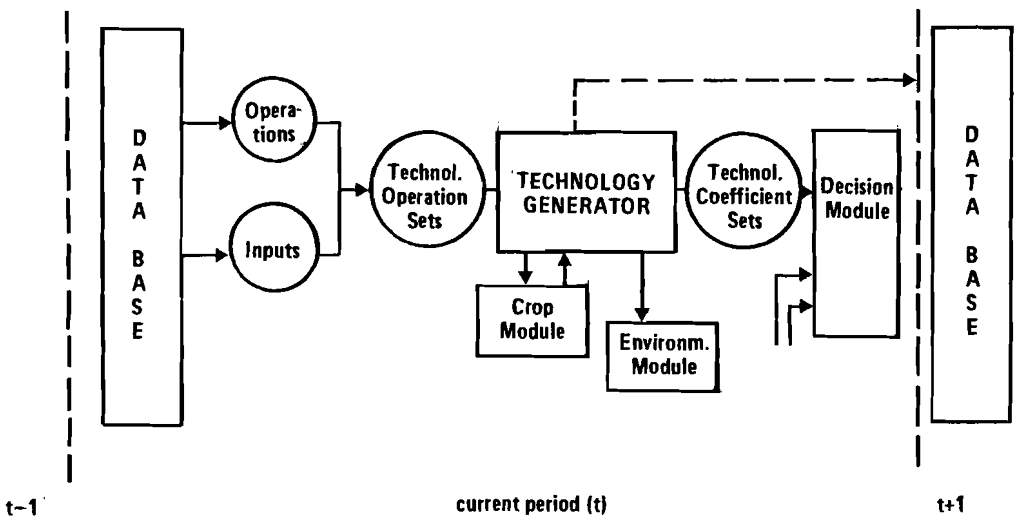

FIGURE 2 The technology module within the model structure.

as well as on the required inputs measured in physical units. The operation sets for crop production technologies as shown in Fig. 3 form the basis for analyzing the critical phases of the production processes actually considered. Additionally they enable issues of particular relevance to

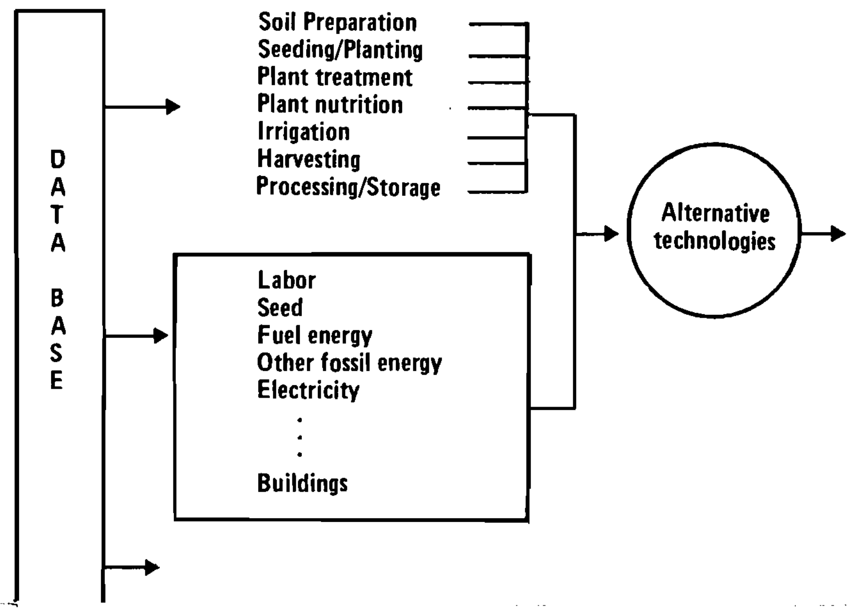

FIGURE 3 The structure of technology operation sets (crop production).

be identified (for example, technological activities requiring a particularly high input of energy, uncontrolled impacts on the environment, etc.).

Efficient use of the operation sets is only possible if the levels of inputs necessary for carrying out the operations or activities which form the operation set are well specified. This does not, of course, mean that the level of disaggregation shown in Fig. 3 should be possible or even necessary for each specific case. However, it does not seem promising to have too high a level of aggregation from the outset because the aspect to be taken into account might be omitted or not represented sufficiently.

When developing the data base for a particular case study, as many techniques as possible for producing an individual commodity should be described in order to have a broad basis for generating alternative technologies for our model system. The data to be collected can of course also be used for special analyses, particularly in the field of technological forecasting. The major sources for setting up a data base on technologies are the following:

- information on technologies presently applied in the case study regions
- information on technologies presently applied in other regions with similar or at least comparable natural conditions
- technological concepts which could be adopted for practical use within a relatively short time period or without excessive investment

- information about advanced or even new technological solutions which could be used for the further development of agricultural production

In order to collect all the data required, close collaboration with experts preparing the case studies is necessary. Furthermore, we are aiming at strengthening present collaboration with institutions recommended by the NMOs as well as by international organizations such as the FAO. The data base will of course be available to all our collaborators for use. In this way we hope to make a useful contribution to the resolution of the very complex problems of technological transformation, which are some of the most crucial factors in increasing agricultural production.

5.3. THE DECISION MODULE

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The decision module of the general model structure is designed to fulfill the following three principal functions.

- It should connect the regional agricultural production system, which is the focus of the modeling effort, to the other sectors of the economy including other agricultural regions. This connection will be accomplished by making the prices and quantity constraints of purchasable inputs and salable commodities exogenous to the model. Furthermore, societal influences on agriculture which cannot be expressed through price or quantity constraints can be explicitly expressed by specific policy variables. The recursive nature of the model allows the results of this interaction to be made known so that policy and price variables can be changed if the results are not satisfactory at any one decision stage. In this way the connection can be interactive.
- It should choose the desirable production techniques and their levels for each time period. The physical simulation modules (i.e. the technology, crop and livestock, resource adjustment and environmental effect modules) generate a set of possible production techniques for each time period. The decision module uses economic criteria to pick a limited subset of these and to specify the level of each, maximizing an economic objective function subject to a given set of resource and other constraints. Knowledge concerning which techniques were chosen and their levels is then fed back to the physical simulation modules where it influences the generation of the next set of possible production techniques.
- It should determine the changes in resource and capital stocks within the specified regional agriculture. Some level of depreciation of the capital stock as well as degradation of natural resources, especially arable land, results from the chosen production activities. Also, various investment activities chosen as part of the decision process add capital and ameliorate certain undesirable changes in the natural resources. The resultant net changes in the resource and capital stocks are determined in the decision module and their effects change the constraint set for the next decision period.

In order to accomplish these tasks, the decision module is divided into two components. Figure 1 shows where the decision module fits within the complete model and its functional division. The activity analysis component optimizes agricultural production for each decision period. The interface creates and/or updates the necessary activity and constraint vectors that comprise the activity component.

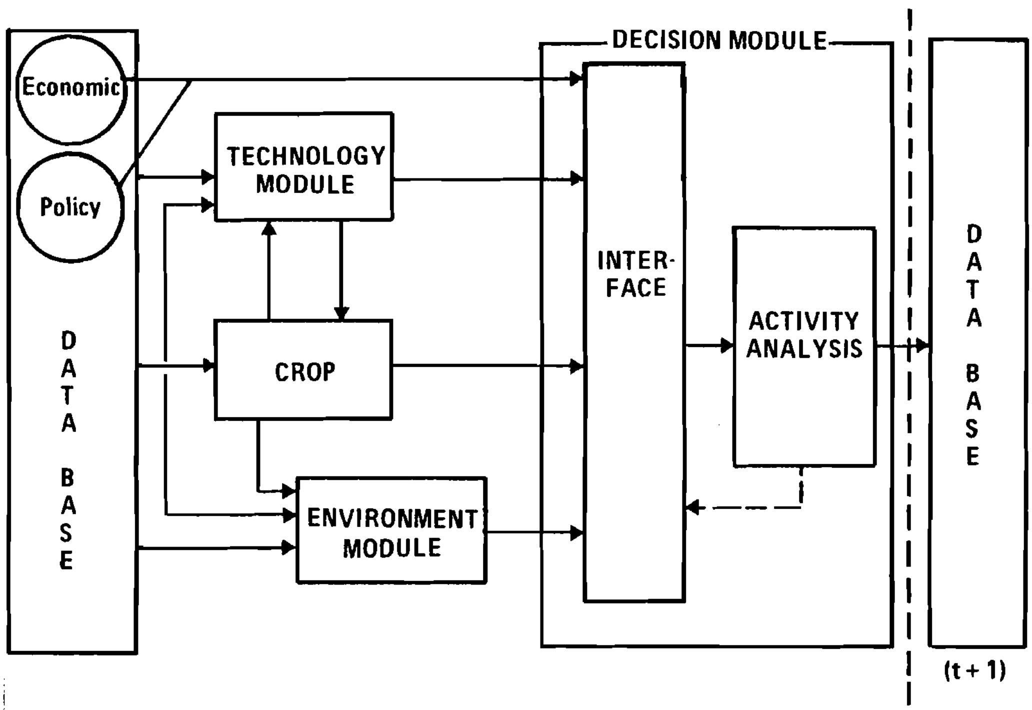

FIGURE 1 Decision module structure.

It is presently planned to use a linear programming model for the activity analysis. An LP model was chosen because of the high level of disaggregation we wish to consider, the ease with which engineering and agronomic data can be incorporated, and our desire to test normative scenarios of future agricultural production. The LP model will operate in a standard way, optimizing the physical relationships specified in the alternative production activities in accordance with economic criteria specified in the objective function. In doing so, a limited set of preferred production techniques will be chosen and the type and quantity of inputs used and commodities produced will be specified. The general types of activities and constraints to be considered in the LP component, with an example of each, are given in Table 1. Table 2 takes just one of the activity categories, livestock production, and shows a more complete list of the constraint, transfer and accounting rows that would be involved.

The interface component of the module serves a mechanical as well as a logical purpose. Mechanically, it will be a set of computer routines that manage the large volume of data involved in creating an LP matrix and updating it for the 20 to 25 recursive solutions that will constitute a complete model run. Logically it will be the connection point for economic and policy data from outside the region, will create the investment activities, will maintain an account of the resource and capital stocks, and, if necessary, will act as a preselector for production and processing activities.

TABLE 1 Activities and constraints.

Activities	Constraints
Input Acquisition – nitrogen	Natural Resources – land
Crop Production – wheat	Capital – machinery
Livestock Production – dairy	Variable Inputs – fuel
Processing – feed compounding	Intermediate Products – forage
Output Selling – corn grain	Production Wastes – manure
Investment – soil amelioration	Environmental Effects – soil sediment

TABLE 2 Livestock activities – bovine (dairy, beef, draft).

INPUTS		
Variable	Physical Capital	Other Capital
Labor	Feed storage	Breeding stock
unskilled	Feed handling equip.	Technical knowledge
skilled	Pens, barns, fences	Management
Energy	Milking equipment	Operating capital
fuel	Waste handling equip.	
electricity	Waste storage	
space heating		
Feed		
dry matter		
energy		
protein		
Veterinary medicine		
Bedding		
OUTPUTS		
Commodities	Joint Products	
Milk	Manure	
Milk products	Milk processing wastes	
Beef	Slaughter wastes	
Hides		

As the connection point for external economic and policy data, the interface will create buying and selling activities, generate expected prices, set the economic objective function coefficient and interpret the policy variables in a meaningful form for the LP model.

The investment activities within the LP will need to have an expected present value that considers not only their contribution to present production but also their contribution to all future periods over which they continue to exist. Thus the interface will need to generate longer-term expectations and to be able to attach discounted present values to each possible investment activity.

If the number of possible production and processing activities generated by the physical simulation modules is deemed to be too large for ease of solution of the LP model, the interface will also need to act as a preselector to choose the best subset of them. While the criteria for this preselector will need to be case-specific they will generally be based on the physical feasibility of the production technique given the available resources, and its economic likelihood of being chosen considering the expected prices of its main inputs and outputs.

5.4. THE ENVIRONMENT MODULE

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The environment module is designed for studying the interactions between agriculture and the environment. The general questions we want to investigate are as follows.

(1) What is the optimal level of interaction between agriculture and the environment?

(2) What are the optimal policy instruments for reaching the levels of interaction between agriculture and the environment that are either found in our investigation or arrived at by expert judgment?

(3) At what level must these policy instruments be set?

An analysis of question (1) essentially requires the internalization of all externalities. The underlying assumption for such an investigation is that the decision agents exhibit altruistic behavior, given the economic and technical constraints. For this reason, no policy variables are analyzed. Since we know that the assumption of altruistic behavior is hardly valid in reality, questions (2) and (3) require investigation as well.

Although question (1) is very important, finding a precise answer is extremely difficult. Therefore, the optimal policy instruments and their levels are usually sought in the context of setting standards.

Policy instruments included in such a study might be of two kinds: direct and indirect. Direct policy instruments are referred to as those which act on the physical part of the system, such as per hectare restrictions of runoffs, restrictions on leaching of chemicals, water treatment, or restrictions on chemical balance at the farm or regional level. The indirect policy instruments rely on economic incentives to achieve a certain level of environmental quality. Instruments of this kind are excise taxes, effluent charges, market rights for chemicals, and vocational training.

Some of these instruments are mutually exclusive, while others can be applied simultaneously. From a modeling point of view, some are fairly easy to include, but others are quite difficult. For example, a policy which relies on vocational training essentially requires that human capital be considered as an input in the model.

One part of the criterion function used for such an analysis should be a cost damage function which quantifies the costs of changing the environmental quality. The costs are expressed as losses in benefits and/or as costs for removing pollutants.

The environment module consists of two parts:

- the generator of resource adjustment and environmental coefficients
- the resource adjustment module

In the resource adjustment and environmental coefficient generator, several processes can be recognized. Each of them is assumed to produce resource adjustment coefficients and environmental coefficients. In principle, the two are complementary, e.g. the soil loss caused by water erosion requires resource adjustment while having at the same time environmental effects. The relative importance of each of the two is determined by the process itself and regional circumstances.

Table 1 lists the most important processes according to the coefficient distinction described.

TABLE 1 Processes to be considered in the resource adjustment and environmental coefficient generator.

Process	Resource adjustment coefficients	Environmental coefficients
Water erosion	Loss of soil, nutrients	Sediment, nutrients, biocides
Wind erosion	Loss of soil, nutrients	Sediment
Salinization	Salt content	
Sodication	Salt composition	
Acidification	Acidity	
Toxification	Accumulated toxic elements	
Mineralization	Material losses	
Humification	Material accumulation	
Leaching	Nutrients,salt content	Nutrients, biocides

The importance of the processes will change from location to location. Some of them cannot occur at the same time as others; for example, water and wind erosion.

We are interested in the role of agriculture in these processes, and, in particular how agricultural production may affect itself. Therefore, we need to be able to convert the coefficients resulting from the processes considered into those soil and site properties (part of the data base) that codetermine the agricultural production level. Whether this conversion is possible or not depends mainly on the kind of resource adjustment coefficients obtained from the coefficient generator and the kinds of soil and site properties that are required as input characteristics for the crop module. In the crop module, built at the Centre for World Food Studies at Wageningen, those soil characteristics are yield-codetermining that are easily related to the outcome of the environment module (Centre for World Food Studies, 1980).

The following examples may help to clarify this conversion. Once it has been decided what kind of crop will be grown on a particular type of land, causing a certain amount of soil loss, it will be necessary to convert the soil loss to another soil property or even properties because the crop module is only sensitive to that property or those properties. An example of such another property may be the amount of organic matter in the surface soil horizon; it depends on the soil loss and may instead of the soil loss affect the yield estimated by the crop module. This can be done using the soil bulk density; this simply converts soil loss to loss in the thickness of the surface soil layer, and this in turn means a change in the amount of organic matter.

Sodication (sometimes called alkalinization) is a change in the salt composition in the soil. This change affects several soil properties: the stability of the soil structure will be affected, which will cause changes in hydraulic conductivity, air permeability and plant-available water. The conversion of the salt composition to the last three characteristics considered as inputs for the crop module requires relationships developed in the particular field of specialization. This last example is shown in Fig. 1.

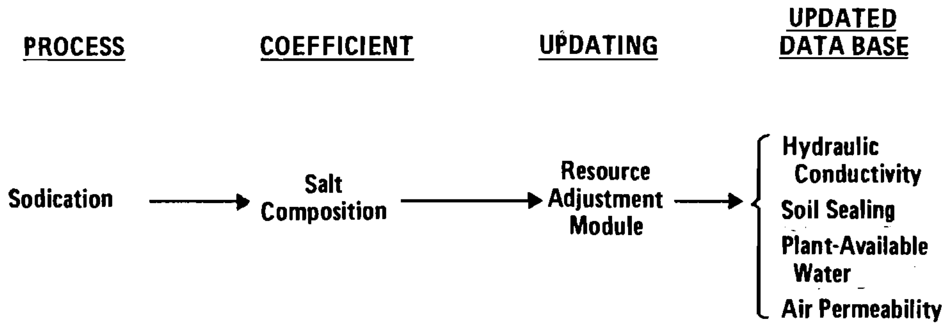

FIGURE 1 The resource adjustment module with respect to sodication (alkalinization).

Owing to the limited manpower available, we have to rely heavily on the modeling work done by others in this field. Our aim is to select those models built elsewhere which require the least calibration when applied to various case studies. It is hoped that CREAMS (Knisel, 1980), a field-scale model for chemicals, runoff, and erosion from agricultural management systems, meets this prerequisite and can be used for generating the coefficients. The processes of salinization, however, are not covered by this set of models and hence have to be taken from another source (Kovda and Szabolcs, 1979). The problem of applying a field-scale model to a larger area, e.g. a watershed, has to be solved if CREAMS is to be the model that is finally chosen.

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5.5. ENERGY AND AGRICULTURE INTERACTIONS*

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5.5.1. Introduction

Energy is an important resource for agriculture and at the same time agriculture is a resource for energy. Current work considers this relationship with regard to the developing countries, for which both these linkages are important. Depending on the country, 30% to 70% of the intermediate input costs of agricultural crop production are directly or indirectly related to energy; however, agriculture provides 20% to 90% of primary energy through the supply of noncommercial energy (wood, waste, dung, etc.). This interactive system of energy and agriculture is shown in Fig. 1. It can be seen that while some dung and residues are used by the agricultural sector itself in the form of fertilizer and feed, the rest is used as an energy resource in unprocessed form in rural households and rural industries. This leads to savings of investment and of imports that would otherwise have been required to obtain commercial energy. The savings may be used to purchase more "processed energy" (fertilizers, diesel oil, pesticides, etc.).

Thus it is only when the energy–agriculture interactions are examined in an integrated system-analytic modeling framework that the answers to several policy issues become evident. Such issues are, for example, the following.

- What could be the cropping allocation patterns in the future if the different amounts of nutrition and energy that crops and crop residues provide are considered along with the different levels of inputs required per hectare?
- How much land of various types (woodland, forest land and fallow arable land) can be allocated to energy crops (wood, cassava and sugar cane for gasohol, etc.) when land is also needed to produce food crops?
- What are the effects of energy prices on choices of farming technology?

*This work is supported by the Centre for World Food Studies (CWFS), Amsterdam and is being carried out by the Resources and Environment Area (REN) at IIASA. It was conceived as an input to the case study of Bangladesh currently being carried out at CWFS, but it is generalized here so that it is applicable to the FAP models.

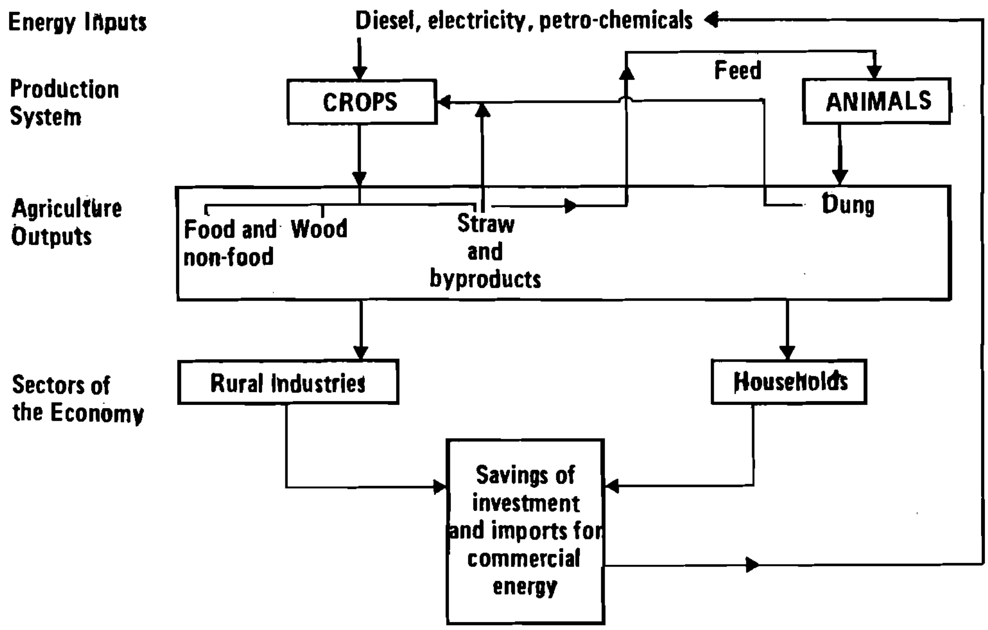

Figure 1 Energy inputs to and outputs from agriculture.

- What is the agricultural importance of animals which provide manure and small-scale draft power, but consume crop residues and feeds? What are the relative merits of bullocks and tractors for various classes of farmers having different amounts of landholdings, capital availability, etc.?
- To what extent can energy production from agriculture save net energy imports?

These and other issues can be examined in such an integrated system-analytic modeling framework.

5.5.2. Energy for Agriculture

Direct and indirect energy uses for agriculture relate to mechanization, irrigation, fertilizers and pesticide application. Table 1 shows the energy consumed by the developing countries in different regions of the world. In the developing countries the respective percentages for these energy uses are 26%, 14% and 60%. In Southeast Asia specifically, they are 13%, 20% and 66% respectively. Thus fertilizer production makes the largest single use of energy for agriculture. (Pesticides, if separately accounted for, use 1% to 4% out of a total of 60%.)

It is therefore important to consider technological and other long-term changes in the model relating to energy use, some options for which are listed in Fig 2. Among the other changes related to energy could be crop mix. Table 2 indicates the energy used for different crops in the UK and shows that peas may be the most effective way of obtaining (food) calorie and protein requirements, followed by wheat and oats.

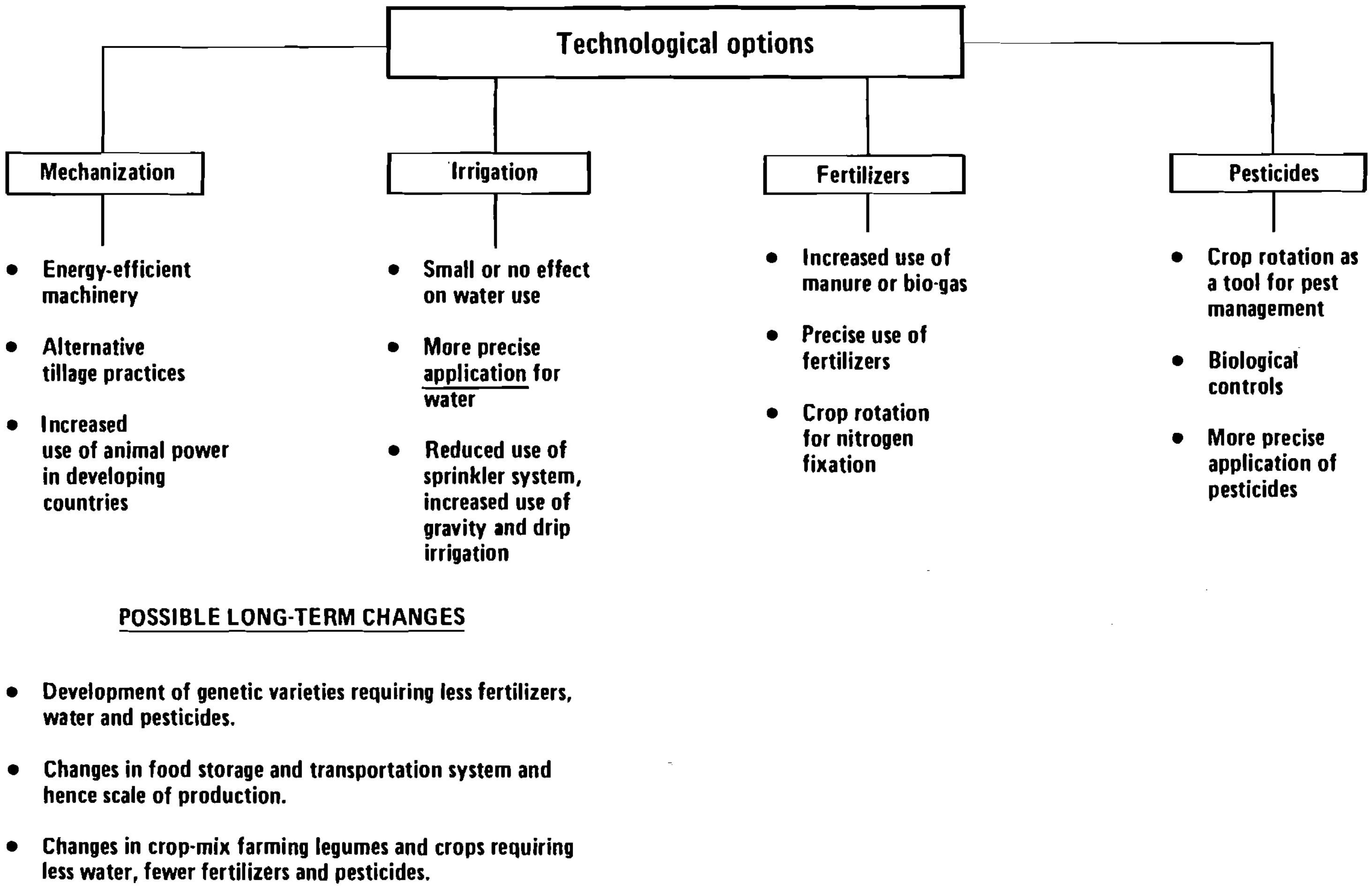

FIGURE 2 Technological options in agriculture that affect the energy required for agriculture.

TABLE 1 Percentage distributions of direct and indirect uses of commercial energy in agriculture.

Region	Energy in Agriculture in 10^9 J	Percentage Distribution			
		Fertilizers	Mechanization	Irrigation	Pesticides
Africa	2	53	42	3	1.6
South East Asia	20	66	13	20	0.5
Latin America	11	48	46	4	1.6
China	15	71	9	16	4.3
Developing Countries	49	59	26	14	1.0
Developed Countries	214	39	57	2	0.9
World	260	43	50	4	2.1

TABLE 2 Cropwise energy requirements per ton of grain in the UK.

Crops	Fertilizers/ha (GJ (10^9 J)/ha)	Energy (GJ/ha)	Net yield (t/ha)	Input energy/t (GJ/t)	Food calories/input energy (GJ/GJ)	Protein/input energy (kg/GJ)
Barley and oats	8.9	15.7	3.4	4.6	3.0–3.5	16.3–28.3
Maize	5.5	26.4	5.0	5.2	2.9	18.3
Wheat	11.7 (winter)	18.9	4.2	4.9	2.8	25.0
	6.9 (spring)	13.7	3.6	3.8	3.7	31.8
Potatoes	18.7	36.1	23.8	1.5	1.9	11.2
Sugar beet	15.2	27.4	34.2	0.8 (beet)	3.6 (beet)	0
				4.6 (sugar)	4.1 (sugar)	0
Peas	0.4	10.9	3.9	2.8	5.2	80.4

Each of these options, along with other resource implications such as land use, capital requirements, etc., is considered in the modeling framework.

5.5.3. Energy from Agriculture

As discussed earlier, agriculture provides a large percentage of rural energy, and therefore enters the modeling work in two ways:

- through the selection of crops and livestock which also produce primary energy resources as byproducts
- through activities that further process agricultural residues in their primary energy forms in order to obtain more processed secondary energy forms through conversions as illustrated in Fig. 3.

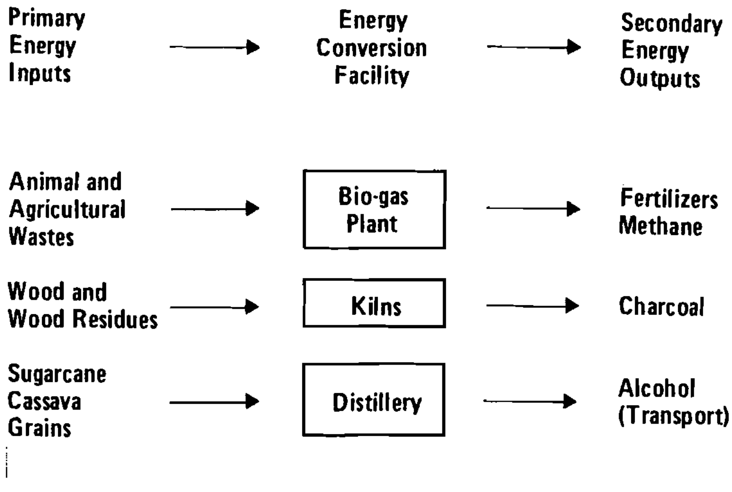

FIGURE 3 Energy from agriculture.

Thus the model would consider using primary energy inputs directly as well as processing part of these to obtain more efficient forms of secondary energy.

5.5.4. Present Status of the Work

Mathematical equations and corresponding tableaux have been prepared for a linear programming model where the objective function is to maximize the revenues from crop and energy production. These take into consideration:

- crop commodity classes of 19 categories
- 12 activities of energy production and purchase (these include the production of primary and secondary energy products e.g. charcoal, bio-gas, and gasohol,and final energy purchase)
- six activities of irrigation methods
- 12 activities of fertilizer provision (four for each type of nutrient, nitrogen-, phosphorus-, and potassium-based, being purchase of chemicals, bio-gas, manure and crop residues)

- four activities of draft power, including two types of tractors and two types of animals
- monthly requirements of labor, water and draft power, and availability of crop residues
- requirements for food and energy by income class, and availability of land and other resources such as tractors, draft animals, or cash

In addition, the model has the flexibility of introducing several land classes and/or subregions. Energy demand for cooking, lighting, and village industries are considered in competition with energy demand for agriculture. Data collection for various activities for Bangladesh is in progress. Some of the modeling framework and data may be relevant for other developing countries as well.

5.6. US CASE STUDY: LONG-TERM SUSTAINED AGRICULTURAL PRODUCTIVITY IN RELATION TO ENVIRONMENTAL IMPACTS AND RESOURCE LIMITATIONS

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Iowa State University over a period of years has developed a set of models which allows detailed analysis of agricultural productivity, resource structure, income results, resource limitations, technology, land and water use or conservation and environmental impacts. A wide range of models and modeling variations can be used in developing the Task 2 Case Study for the United States. The basic models include the following.

- An econometric recursive simulation model which incorporates, at the national level, commodity and resource supply and demand relationships, resource employment and structural relationships and all other major relationships of an economic sector
- A set of national and interregional programming models which delineates the nation into as many as 223 producing regions and 9 classes within each, and incorporates a detailed transportation submodel to interrelate producing regions and market regions. These models incorporate endogenous crop and livestock sectors, a very wide range of technologies which relate agricultural production to soil loss (erosion), chemical transport to animal wastes, land productivity, sediment delivery, and nonpoint pollution. For each land class in each region, activities are specified which estimate soil loss in relation to
  (1) land characteristics
  (2) climate conditions
  (3) crop mix grown
  (4) conservation practices used (e.g., contouring, terracing, etc.)
  (5) tillage practices (conventional plows, no-till, etc.)
  (6) chemical use

These models have been used widely for the US Department of Agriculture in estimating future resource productivity in relation to resource restraints and environmental impacts (the National Water Assessment for the Water Resources Council and the Environmental Protection Agency), in estimating future production and export potential against soil conservation (erosion) goals and productivity maintenance (the analysis of the Resources Conservation Act and the Rural Clean Water Acts for the Soil Conservation Service) and for various other purposes. They are extremely detailed and are under further expansion for the forthcoming 1985 Resources Conservation Act evaluation, guided by a national committee from all regions of the United States.

- A set of quadratic programming models which also incorporate national and regional detail (150 regions). These models incorporate econometrically estimated commodity demand functions, and also transportation submodels, and are applicable to environmental impact analyses and general productivity and policy analyses.
- A set of energy models. These are generally of a mathematical programming nature. They allow investigation of energy supply and price impacts on agriculture, the interactions between liquid fuel (ethanol) production, spatial agricultural patterns, and environmental and soil loss impacts. They, too, provide detail for 105 or 150 regions. (Some analysis for energy is completed by the econometric simulation models.)
- A set of hybrid or linked models which combine the national econometric simulation models and the detailed regional and interregional programming models. These models, incorporating econometrically estimated resource and commodity supply and demand relationships, are recursive with prices determined in the econometric module, and resource demands and commodity supplies determined sequentially in either the regional or national programming component. They have been used for policy, productivity, environmental and other analyses.

Initially in the IIASA Task 2 Case Study, we are combining parts of the above models to provide a regional model for analysis of long-term sustained agricultural productivity in relation to resource restraints and environmental impacts. We select a region for the Task 2 Case Study in order that the study will be comparable with Task 2 studies of other countries. (We already can accomplish the general analysis at the national level and for a large number of specific regions, each with its own soil, climatic and ecological characteristics.) For the analysis, we have selected the state of Iowa as a region. Iowa is subdivided into 12 subregions (the Soil Conservancy Districts of Iowa), each with five land classes. A programming model (of the general nature of the second of the points mentioned) is specified for the Iowa region and its subregions and individual land classes. Soil loss and the land productivity decline are measured for each crop mix, conservation practice and tillage method on each land class and each subregion. Thus, resource supplies and commodity demands are generated in the Iowa region via the programming module.

The national econometric, recursive simulation model generates resource and commodity prices and other relationships. The United States agricultural sector aside from the Iowa region is represented aggregatively in the econometric module in terms of commodity supply, resource demand, and other relationships. Thus, as market prices are generated by the econometric model, the United States outside of Iowa responds in resource demands and commodity supplies in terms of statistically estimated relationships. The Iowa region, and its subregions and land classes, is modeled to respond through the linear programming component; Iowa commodity supplies and resource demands, generated through the programming module, are added to those of the rest of the nation, generated through the aggregated econometric component. The Iowa regional component, with the 12 subregions of five land classes each, also generates a set of soil loss factors and related environmental and productivity variables which reflect immediate output and long-term productivity.

The initial model is now operational. It can indicate levels of present productivity which (a) are at maximum levels without regard to the extent of soil erosion and nonpoint pollution, or (b) must not be exceeded if soil loss and conservation are set at levels estimated to maintain long-term productivity and hold nonpoint pollution at acceptable levels. (A sediment delivery component, as used in some of our national models, is necessary for the latter purpose.) In generating these tradeoffs, the model indicates the conforming technologies in terms of (a) crop mix, (b) livestock production, (c) conservation practices, (d) tillage methods, (e) animal waste and chemical fertilizer combinations, etc.

We can now summarize some results of a base solution to the Iowa Task 2 Case Study. In this solution, net returns to crop production are maximized without regard to the extent of soil erosion for 1975 and 1985. Total acreage, soil loss, commercial nitrogen use, and energy input per acre are presented for 1975 and 1985 in Tables 1 and 2. In addition, crop yield, cost, and nitrogen use per acre are indicated for 8 crops. All information is reported on the basis of five land classes, and is also available for each of 12 spatially delineated producing areas. Comparison of the 1975 results with actual data shows that the model closely simulates the Iowa crop production sector.

The regional model, which can immediately be translated into the national model and used for the Resources Conservation Act analysis which we are performing for the US Department of Agriculture, has great promise in the extensions which we wish to work out jointly with IIASA. Many further steps are contemplated, even though our model set has been applied extensively over a long period of time for American policy makers. For example, we hope to improve our sediment delivery module which we have used in several previous national–interregional analyses. We will do so first in the Iowa regional model developed cooperatively with IIASA, then incorporate it in our national model for use in the 1985 analyses for the nation's Resources Conservation Act. Together with agronomists at Iowa State University, other universities and the Soil Conservation Service of the US Department of Agriculture, we are in the process of making yield productivity endogenous in relation to land use (crop rotations and mixes) and technology (chemical and organic farming methods, conservation farming practices, tillage methods, etc.). We will also specify the model so that it can endogenously induce investments in soil loss abatement (i.e., soil conservation as represented in crops produced, chemicals used, conservation practices applied, tillage methods used, etc.) as they become profitable to farmers. In instances where these investments are not induced but are "public goals," either endogenous mechanisms or exogenous policies will be modeled to attain them.

The national and regional models are already operational and are in use for national policy purposes. They include vast technical detail and economic relationships. The Iowa regional model, through cooperation with IIASA, is already operational in a middle and useful stage of analysis. Our objective is to modify it further in cooperation and interaction with IIASA and other case study countries over the next two years. We have already made numerous applications and uses of it in the United States.

TABLE 1 Results of base solution to Task 2 Iowa Case Study Model, 1975.

	Land class					
	I	II	III	IV	V	Total
Iowa Total						
Acres (1000s)	5735	9107	4916	385	12	20155
Soil loss (tons)	28890	21022	65028	7545	51	122535
Nitrogen (tons)	208	246	139	7	0	601
Energy/acre (MMBTU)						
Diesel	1.69	1.62	1.70	1.37	0.98	1.65
LPG	0.72	0.53	0.53	0.30	0.24	0.58
Electricity	0.05	0.04	0.04	0.03	0.03	0.05
Natural gas	0.09	0.07	0.08	0.05	0.05	0.08
Total	2.55	2.27	2.35	1.75	1.30	2.36
Corn						
Yield/acre (bushels)	111	102	98	68	36	104
Cost/acre (dollars)	77	81	96	85	79	83
Nitrogen/acre (lbs)	101	102	102	97	109	102
Legume hay						
Yield/acre (tons)	0	3	3	3	0	3
Cost/acre (dollars)	0	73	78	69	0	73
Nitrogen/acre (lbs)	0	3	2	3	0	3
Nonlegume hay						
Yield/acre (tons)	0	3	2	2	1	2
Cost/acre (dollars)	0	54	58	53	58	55
Nitrogen/acre (lbs)	0	22	16	20	27	20
Oats						
Yield/acre (bushels)	0	59	47	46	38	56
Cost/acre (dollars)	0	34	30	33	29	34
Nitrogen/acre (lbs)	0	5	4	5	5	5
Sorghum						
Yield/acre (bushels)	0	84	73	42	0	60
Cost/acre (dollars)	0	48	46	45	0	46
Nitrogen/acre (lbs)	0	69	83	78	0	80
Soy beans						
Yield/acre (cwt.)	17	16	15	12	0	16
Cost/acre (dollars)	59	62	63	60	0	61
Nitrogen/acre (lbs)	1	1	1	1	0	1
Wheat						
Yield/acre (bushels)	0	37	0	28	0	34
Cost/acre (dollars)	0	39	0	38	0	39
Nitrogen/acre (lbs)	0	48	0	47	0	47

TABLE 2 Results of base solution to Task 2 Iowa Case Study Model, 1985.

	Land class					
	I	II	III	IV	V	Total
Iowa Total						
Acres (1000s)	5735	9474	5326	591	278	21405
Soil loss (tons)	23708	27174	75072	8012	2551	136516
Nitrogen (tons)	254	299	175	14	6	749
Energy/acre (MMBTU)						
Diesel	1.74	1.66	1.78	1.34	0.98	1.69
LPG	0.86	0.60	0.61	0.40	0.24	0.66
Electricity	0.06	0.05	0.05	0.04	0.03	0.05
Natural gas	0.11	0.08	0.08	0.06	0.05	0.09
Total	2.78	2.39	2.52	1.84	1.30	2.50
Corn						
Yield/acre (bushels)	111	101	96	88	35	103
Cost/acre (dollars)	77	81	94	101	81	83
Nitrogen/acre (lbs)	102	102	100	103	105	101
Legume hay						
Yield/acre (tons)	0	4	2	0	0	3
Cost/acre (dollars)	0	65	77	0	0	70
Nitrogen/acre (lbs)	0	3	2	0	0	3
Nonlegume hay						
Yield/acre (tons)	0	2	2	2	1	2
Cost/acre (dollars)	0	56	58	51	49	53
Nitrogen/acre (lbs)	0	18	17	22	23	21
Oats						
Yield/acre (bushels)	0	63	48	45	29	52
Cost/acre (dollars)	0	33	30	35	34	33
Nitrogen/acre (lbs)	0	5	4	5	5	5
Sorghum						
Yield/acre (bushels)	91	0	72	0	0	79
Cost/acre (dollars)	44	0	46	0	0	45
Nitrogen/acre (lbs)	78	0	82	0	0	80
Soy beans						
Yield/acre (cwt.)	17	16	15	14	0	16
Cost/acre (dollars)	59	62	63	64	0	62
Nitrogen/acre (lbs)	1	1	1	1	0	1
Wheat						
Yield/acre (bushels)	0	44	0	0	0	44
Cost/acre (dollars)	0	38	0	0	0	38
Nitrogen/acre (lbs)	0	45	0	0	0	45

The extensions and further specifications then will be worked into our national model with its 105 individual regions with five to nine land classes each (depending on our own judgments and those of our national advisory committee).

Members of the Economics and Statistics Service of the US Department of Agriculture are cooperating with Iowa State University in the IIASA Task 2 models. During April 1981, members of this team are to spend time at IIASA in applying, evaluating and extending the model. One staff member will remain at IIASA for three months to continue these activities.

Our models already are well advanced and applicable for policy analysis purposes. However, there still is a wide range of features which we plan to include in them. Given the potential size of such models, we need to decide on the number of variables to make endogenous, without producing overburdening computational costs but still retaining "real world" characteristics.

The basic nature of the models has been summarized in two papers presented at IIASA workshops: A Proposal for the IIASA Task 2 Iowa Case Study (September 1980) and An Update of the IIASA Task 2 Iowa Case Study (February 1981).

5.7. LONG-RANGE IMPACTS AND CONSEQUENCES OF TECHNOLOGICAL DEVELOPMENT IN HUNGARIAN AGRICULTURE (A CASE STUDY)

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Two research projects were recently completed on the developmental problems of Hungarian food and agriculture. In cooperation with IIASA the second version of the Hungarian Agricultural Model (HAM-2) was constructed in 1979. The model focuses on the economic aspects of the system, and using HAM-2 mid-range (five-year) projections were made. In a research project organized by the Hungarian Academy of Sciences, the agroecological potential of Hungary was stressed. The main aim of the latter study was to explore the biological potential of production growth up to the year 2000. These two projects offer an excellent starting point for further investigations in which the economic, technical, ecological and environmental elements of agricultural development will be equally considered.

The decision has already been made in Hungary to continue work in this direction within the framework of the new five-year research plan of the Hungarian Academy of Sciences. Task 2 of the FAP at IIASA intends to carry out a series of case studies on limits and consequences of agricultural production. The Hungarian research plan seems to have much in common with the Task 2 objectives and therefore might be considered for inclusion as a Task 2 case study. In this paper the possible objectives, methodology, and organization of an IIASA/Hungarian case study of the Task 2 type are outlined.

5.7.1. Coverage of the Study

In the study we intend to investigate the whole country. Based on geographical and physical characteristics, climatic conditions and existing patterns of agricultural production 10 (or at least 8) producing regions will be considered.

The regions will be the basic units of investigation. The region is the framework within which the major technical, technological, ecological and physical processes will be studied. Within each region a limited number of soil varieties will also be distinguished. The whole country will be covered region by region. (The coverage of the study is outlined in Fig. 1.)

Our investigation is focused on agricultural production systems. By our definition, agricultural systems are based on biological processes and

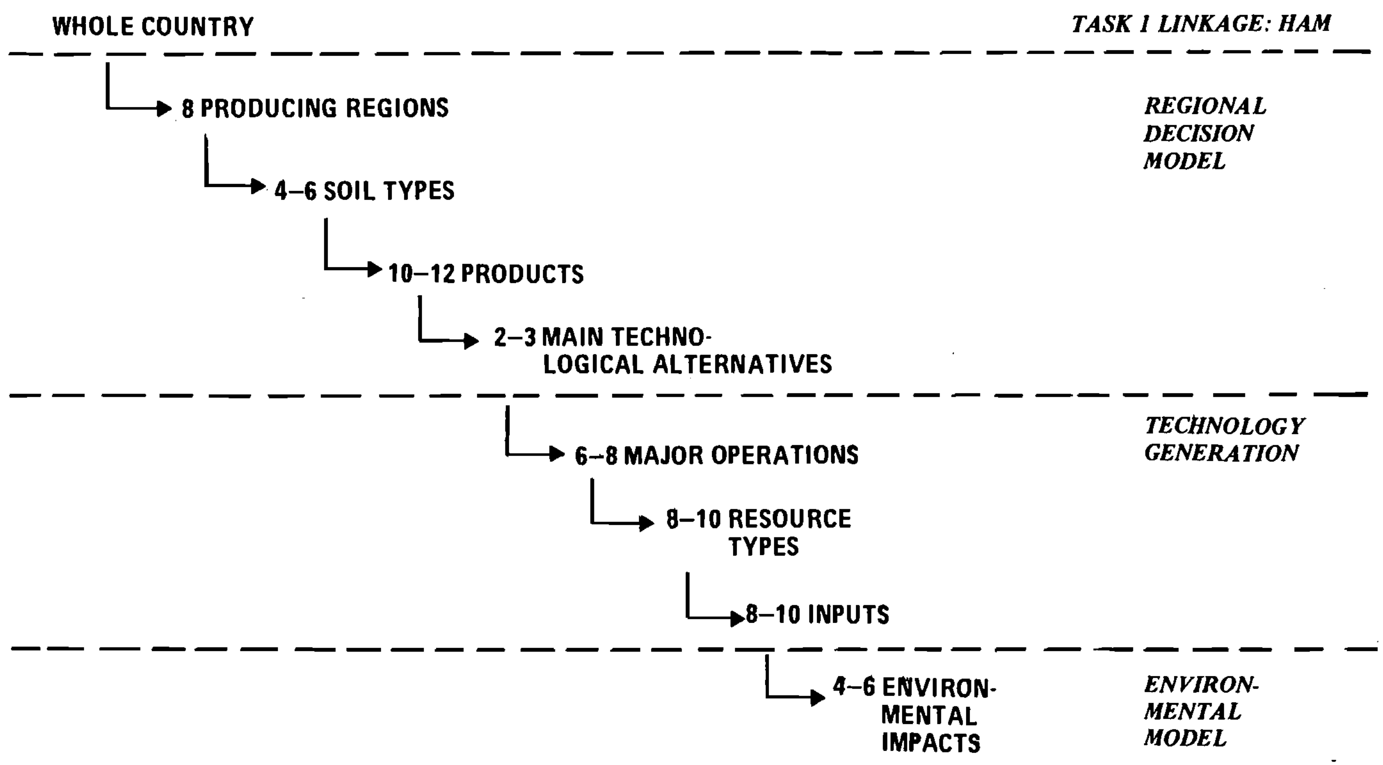

FIGURE 1 Coverage of Hungarian Task 2 case study.

include a biological subsystem (plants, animals). Thus we do not intend to study the whole food chain. Only those processing activities will be considered that are closely related to agricultural production systems and are carried out by typical farms in Hungary (for example, dehydrating alfalfa, drying grain, etc.).

Crop production and animal husbandry will be represented by several commodities or production branches. In the case of crops, major varieties will also be considered. As far as animal husbandry is concerned, our objectives allow us to make the treatment somewhat more aggregated. Commodity classifications of the study should be consistent with HAM-2, and with those of the agroecological study.

Of the natural resources, land will be considered in a relatively detailed way (soil categories, improvement potentials, etc.). Water will also be included. At present irrigation plays only a marginal role in Hungary; however, serious drainage problems exist in several regions. As far as climate is concerned, all regions will be considered as homogeneous. Secondary resources will be studied according to technologies. Choices of technology will include technologies presently used in the region, technologies presently in use in other regions with similar natural conditions, and more advanced technologies that could be adopted in the region. Technologies and secondary resources are relatively detailed in the case study. Special sets of indicators will also be developed to study environmental aspects and aggregated energy consequences.

There is no doubt that the actual decision making mechanism in respect of agricultural technological development has a great impact upon the future. Efforts have also been made to include this factor in our study.

Problems of regional development, except those closely related to agriculture, are excluded from the study.

5.7.2. Methodology

Computer modeling will be used as a basic methodological framework for the investigation. A system of interconnected mathematical models and program packages will be used as a core for the projections.

The problem can be described by a hierarchical model system consisting of the following three levels:

- the determination of a long-term production policy and the description of genetic and technological progress
- investment policy
- production at the regional level

At the first level, forecasts of the price system, investment constraints, the needs of society and of genetic and technological development take place. With the single exception of technological prognosis, all these factors can be regarded as solved, the economic factors being provided by HAM and the genetic prognosis by the Survey of the Agroecological Potential. Linkages with the rest of the model system are yet to be worked out.

The second level of the model system deals only with the long-term planning of agricultural investment, as well as the linkage of overall development with regional spheres. The long-term investment policy can be described by a control problem, where the set of possible controls is given by a system of linear inequalities:

$$B \underline{u}(t) \leq \underline{b}_o(t) \qquad t \in \{1,\dots,T\}$$

The state of the system is determined by a linear system of difference equations:

$$\underline{x}(t+1) = A\,\underline{x}(t) + C\,\underline{u}(t)$$
$$\underline{0} \leq \underline{x}(t) \leq \underline{L} \qquad t \in \{1,\dots,T\}$$
$$\underline{x}(0) = x_o$$

The transfer from the controls to the yields is described by a system of linear inequalities and a nonlinear function:

$$\Omega(u) = \{v;\ D(t)\,\underline{v}(t) + Ex(t) + F(t)\,\underline{u}(t) \leq \underline{f}(t)$$
$$\underline{v}(t) \geq 0, \qquad t \in \{1,\dots,T\}\}$$
$$\underline{Y} = \underline{Y}(u,x,v)$$

and the solution to the problem

$$\text{P-}\max \underline{h}\,((Y^0, Y(u,x,v))$$
$$u \in U$$
$$v \in \Omega(u)$$

is sought, with P-max standing for the Pareto optimality.

That is, the goal is to follow certain prescribed reference trajectories, and not the determination of the local maxima. Such a formulation of the problem allows us to develop a long-term investment policy. The setting up of a number of objectives ensures a balanced development.

The third level serves to investigate production in individual regions, the quality of the habitat, technological effects and other factors taken into account.

The central element of the third level is a region-specific linear programming model, using a static structure, recommended by the FAP's Task 2 as methodological guidelines. This LP model will be used on a recursive basis to determine the optimal product and technological mix for the regions on an annual or three/five-year basis (see Fig. 2). Calculations will probably be made region by region, but the conditions for a multiregional model should also be investigated.

The LP model(s) is (are) related to a set of models. For each region and for each time period, a new model has to be created based on a set of exogenously given parameters expressing the overall trends of technological and biological development. Mutual data or solutions must also be considered for the previous period and projected economic conditions. The new LPs are thus generated by the related models.

The updating of technical, biological, physical and environmental parameters will be based on data banks including actual choices and their dynamics. These data banks will be integrated by a coefficient-generating program package. Physical resource availability has also to be updated, taking into account environmental impacts.

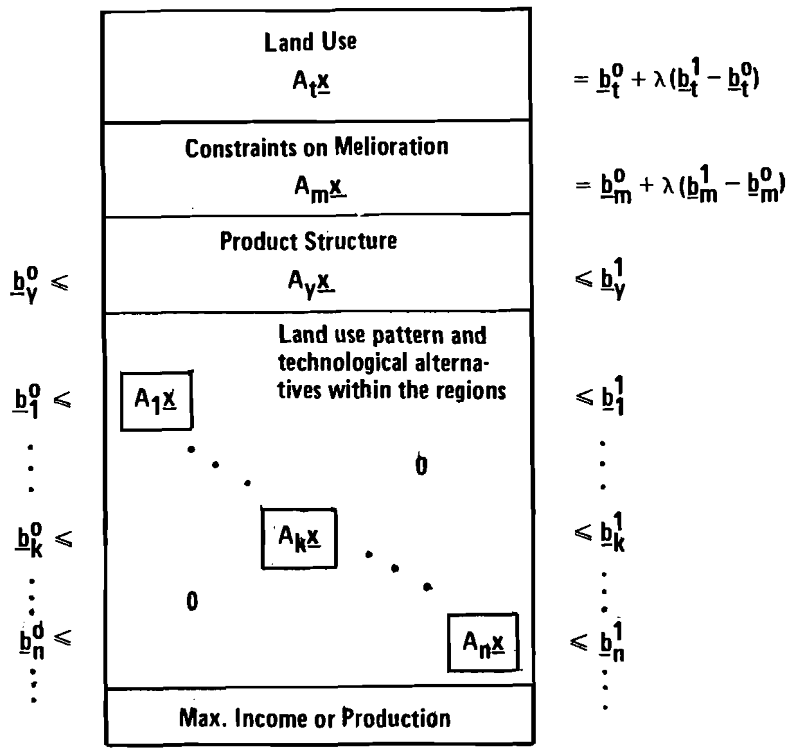

FIGURE 2. Model for regional production structure and technology selection.

The model system outlined above seems to be appropriate for the investigation of a whole range of questions and of scenarios derived from the overall objectives of the study.

5.7.3. Organization and Timing of the Hungarian Case Study

The study will be coordinated by a special committee. The centers of actual work will be the Research Institute for National Planning, the Bureau for Systems Analysis, and the Department of Agricultural Economics at the Karl Marx University of Economic Sciences in Budapest. Probably three other institutions will take part in the investigations: the Research Institute for Agricultural Economics, the Agricultural University and the Institute for Soil Science of the Hungarian Academy of Science.

5.7.4. Schedule of the Study

- Workshop on plans in Hungary, October 1980
- Elaboration of a detailed plan, December 31 1980
- Organization of a working group and core of study, December 31 1980

  - Research Institute for National Planning
  - Bureau for Systems Analysis
  - Karl Marx University of Economic Sciences
  - Institute for Soil Science
- Selection of the first region, starting with data collection, March 1981
- Detailed description of methodological framework, May 1981
- Model for pilot region, August 1981
- Construction of actual model and computer implementation, June 1982.
- Final report on study, March 1983.

5.8. KENYA CASE STUDY: LONG-TERM PROSPECTS FOR FOOD PRODUCTION TECHNOLOGY REQUIREMENTS AND ENVIRONMENTAL IMPACTS

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5.8.1. Introduction

The extent to which natural resources, namely land, climate and water, can produce food and agricultural products is limited. The ecological limits of production are set by soil and climatic conditions as well as by the specific inputs and management applied. Any "mining" of land beyond these limits will, in the long term, only result in degradation and ever-decreasing productivity unless due attention is paid to the preservation, conservation, and enhancement of the natural resource base.

Recent demographic estimates suggest that Kenya's population growth rate of 3.9% is one of the highest in the world. The future domestic requirements for food, industrial raw materials and export crops require sound policies of agricultural land use, especially if sustainability of production is to be ensured in the long term. What is the stable and sustainable production potential in Kenya? What are the levels of population that can be adequately supported by this potential? What trade patterns may be necessary to ensure food self-sufficiency? What are the feasible technological requirements and how can the alternative transition paths be achieved? These central issues of agricultural development planning in Kenya are being investigated within the FAO/IIASA–Kenya collaborative Agroecological Zone Project entitled "Land Resources for Populations of the Future – A Case Study of Kenya" (FAO, 1979). The work in Kenya consists of three phases, as described in the following.

- Phase 1: Analysis carried out on the basis of a 10,000 ha land unit as inventoried from the FAO–UNESCO Soil Map for Kenya. This phase was completed at the end of 1979.
- Phase 2: The basic land unit of 400 ha is inventoried on the basis of a 1:1 million Kenya Soil Map (Kenya, 1980). Detailed country information is used to develop a two-season rainfall inventory, to identify present crop-specific technology and input use, to assess soil erosion, productivity losses and conservation requirements, and to develop methodology for determining crop choice and technology requirements. This methodology, for example, considers aspects of food self-sufficiency and quantifies the input and technology requirements.

- Phase 3: The feasibility and policy implications of alternative technology paths, cropping patterns and environmental conservation are being investigated in conjunction with the IIASA Food and Agriculture Model of Kenya.

Phases 2 and 3 are presently in progress. In this paper the discussion is limited to a description of the overall methodology and preliminary Phase 1 results. The latter should be considered as a "first approximation" of our work on Kenya.

5.8.1.1. FAO agroecological zone methodology

The methodology and computer programs (Fischer and Shah, 1980) for the assessment of agricultural production potential are based on methodology (FAO, 1976, 1979) fundamental to any sound evaluation of land. The methodology developed is used to assess land suitability and potential yield for each of the 18 food crops (including livestock) considered in the study (Fig. 1). (See FAO, 1979 a, b.)

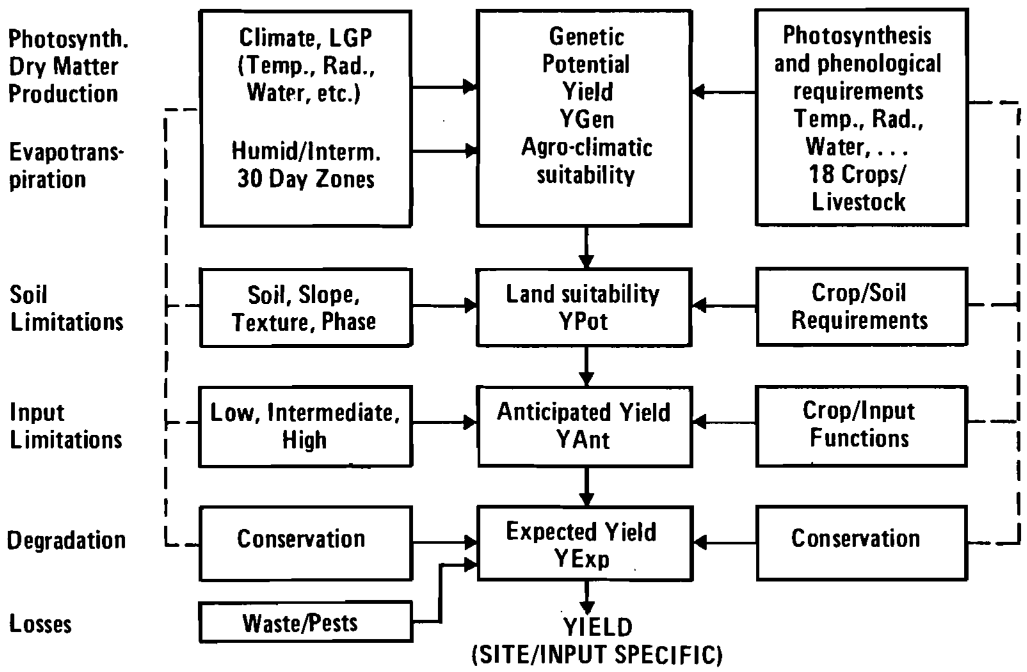

FIGURE 1 FAO methodology and crop yield model.

Fundamental to the assessment is the soil and climatic inventory. This inventory comprises overlay of a specially compiled climatic inventory on to the 1:5 million FAO/UNESCO Soil Map (FAO/UNESCO, 1971–79). The climatic inventory differentiates major climates and length of growing period (LGP) zones at 30 day intervals (e.g. 120–150 days). Measurements of the unique agroecological zones resulting from this combination allow quantification of the land resources in terms of soil and climatic conditions.

The first step in the methodology is to match the climate and LGP inventory with the specific crop requirements to assess the agroclimatic suitability in terms of genetic potential yield. The main features of the climatic inventory created by FAO for the assessment of agroclimatic crop suitability (Kassam, 1979) are as follows.

(a) Classification of crops into climatic adaptability groups according to their fairly distinct photosynthesis characteristics.

(b) Classification of temperature and moisture requirements of crops. The quantification of heat attributes and moisture conditions is based on the actual temperature regime during the growing period and a water balance model comparing precipitation with potential evapotranspiration.

Individual crop productivity rules (Kassam, 1979), as determined for each major climate and length of growing period zone, permit the assessment of agroclimatic crop yield. This is modified by next considering the soil limitations. The resultant potential yield (land suitability) is adjusted according to the input level. Table 1 shows attributes of each of the three input circumstances used in the assessment. Note that the assumption of only three discrete input levels is for simplicity and convenience. The Phase 2 study considers an alternative mix of technology and crops for specific districts in Kenya.

TABLE 1 Attributes of input levels.

ATTRIBUTE	LOW INPUT LEVEL	INTERMEDIATE INPUT LEVEL	HIGH INPUT LEVEL
Market Orientation	Subsistence	Subsistence/ Commercial	Commercial
Capital Intensity	Low	Intermediate	High
Labor Intensity	High	High	Low
Power Sources	Hand Tools	Improved Implements and/or Animal Traction	Complete Mechanization
Technology Employed	Local Cultivars No Fertilizer No Pest Control No Disease Control	Improved Cultivars "Sub-Optimum" Fertilizer Some Chemical Pest and Disease Control	High Yielding Cultivars "Optimum" Fertilizer Chemical Pest and Disease Control
Land Holdings	Small, Fragmented	Small, Fragmented/ Consolidated	Large Consolidated

The input limitations allow the quantification of the anticipated yield. The final step in the methodology is to take account of environmental conditions in terms of productivity and waste losses. The climate, length of growing period, soil characteristics (soil, slope, texture, and phase) and input levels determine the environmental conditions in relation to a particular crop. Degradation of land takes place in many ways, water erosion and wind erosion being the most obvious in rain-fed agricultural production. The productivity loss caused by the rate of soil loss under various climatic, soil, and land use circumstances has been quantified in the form of a degradation model (Arnoldus, 1980, and FAO/UNEP/UNESCO, 1981).

The yield and potential production for each of the 18 crops are assessed for the land actually available for rain-fed production. The available land is derived by making appropriate allowances for nonagricultural land requirement, irrigation land requirement, cash crop land requirement and rest period (fallow) land requirement.

The application of the methodology (Fig. 1) to each unit of available land will result in a number of crops (less than 18) that can be potentially produced. A decision regarding the crop choice for each unit of land depends on the criteria of choice, namely:

(a) maximize calories subject to a protein constraint;

(b) maximize calories subject to the present Kenya crop mix constraint;

(c) maximize profits subject to a target (e.g. year 2000) self-sufficiency in each of 18 food crops.

For a specific land unit, crop and input level environmental conservation will be required to ensure sustainability of production. The degradation model is presently being refined and will be incorporated as a feedback in Phase 3 of the study.

5.8.2. Results

In this paper typical results are discussed. Complete detailed results are given elsewhere (Shah and Fischer, 1981).

5.8.2.1. Assessment of crop-mix production potential

The aim here is to evaluate the maximum production for each crop of the assessment under the assumption of a particular level of inputs and conservation measures. An example of the results for maize (production potential at the intermediate input level) is given in Table 2. Similar results for the three input levels and all crops of the assessment are given elsewhere (Shah and Fischer, 1981).

5.8.2.2. Estimation of potential arable land and degradation hazard

The study shows that if conservation measures are implemented, then the potential arable land for low, intermediate and high input levels is 6.362, 6.776, and 6.893 million ha respectively. However, the percentages of "good" arable land (excluding low productivity land) are 42.8%, 55.1%, and 68% respectively for the three input levels.

The area of arable land presently (1975) under cultivation is about 3.9 million ha. Soil conservation as well as improvement in technology (higher levels of input) will be essential to ensure the availability of arable land for agricultural production.

5.8.2.3. Assessment of population-supporting capacity

The calorie and protein production values for each of these alternative assessments are translated into a population-supporting capacity. Here the Kenyan requirement is assumed to be 2380 calories and 38.8 grams of protein per capita per day. The results for the population-supporting capacity in terms of the ratio of potential to present population are given in Table 3.

TABLE 2 Maize production potential and degradation hazards at the intemediate input level: anticipated situations in 2000.

LAND SUITABILITY (1000 ha)	TOTAL	HIGH	MODERATE	LOW
WITHOUT CONSERVATION	1620	278	374	968
WITH CONSERVATION	3372	964	870	1538
PRODUCTION POTENTIAL (1000 m.t.)				
WITHOUT CONSERVATION			1862	
WITH CONSERVATION			4804	

1975: AREA UNDER MAIZE 1764000 ha, PRODUCTION 2.3 million m.t.
INPUT: LOW/INTERMEDIATE WITH SOME CONSERVATION

2000: DEMAND: LIKELY GROWTH OF PCE AND NO INCOME DISTRIBUTION CHANGE, 4.2 million m.t.
: WITH INCOME DISTRIBUTION CHANGES, 3.6 million m.t.

TABLE 3 The population-supporting capacity of Kenya.

NUMBER OF CLIMATES	4
NUMBER OF ZONES (LGP)	32
NUMBER OF CELLS (AEZ)	1213

	LOW INPUT	INTERMEDIATE INPUT	HIGH INPUT
CONSERVATION			
POTENTIAL/PRESENT POPULATION			
MODE 1: MAXIMIZE CALORIES	0.824	2.302	4.509
MODE 2: PROTEIN CONSTRAINT	0.799	2.255	4.439
MODE 3: PCMIX CONSTRAINT	0.640	1.836	3.681
WITHOUT CONSERVATION			
POTENTIAL/PRESENT POPULATION			
MODE 1: MAXIMIZE CALORIES	0.366	1.181	2.481
MODE 2: PROTEIN CONSTRAINT	0.335	1.132	2.404
MODE 3: PCMIX CONSTRAINT	0.309	0.986	2.107

NOTE: CALORIE/PROTEIN RATIO AT NATIONAL LEVEL IS MET FOR ALL THE ABOVE ALTERNATIVES

The results show that the food demand of the present population in Kenya cannot be satisfied under the assumption of low input levels. This is also the case for the intermediate level of input without any conservation measures, although 98.6% of the population can then be supported. In reality the input level in Kenya is between low input and intermediate input for some crops and higher for others. Some soil conservation measures are also practiced and these are likely to intensify in view of the government policy on environmental conservation. The results show that at least an intermediate level of input with soil conservation measures will be necessary for the food demands of Kenya's population in the year 2000 (the present population will double in size). Note that in estimating the population-supporting capacity the irrigated production (calorie equivalent, Wood, 1980) has been included.

Another interesting aspect of the result is that the population-supporting capacity of the alternative of maximizing calories is higher than the continuing present crop mix alternative. The implication of this is that some changes in the present crop mix will be necessary to increase levels of production of certain food crops.

A comparison of the present and future (Year 2000 demand: FAO, 1979a; Kenya, 1979; and Shah, 1979) demand and potential production for the crops of the assessment has been carried out. The assumption of a minimum self-sufficiency of 85% implies that at least an intermediate level of input with 60% conservation measures is necessary. In general, production potential for wheat, rice and pulses was found to be limited, whereas production in excess of domestic requirement occurs for roots (white potatoes), maize, sugar and livestock products. Table 4 shows the results for the maximize profits/self-sufficiency scenario for the case of high input with conservation.

TABLE 4 High input with conservation: maximize profits/self-sufficiency.

Surplus Production		
Roots* (X 10.8), Maize (X 1.3), Sugar (X 1.9), Livestock (X 10.9)		
Value of Production (Mill. $1975):	**4950**	
Labour (Millions):		**11.79**
Labour Cost (Mill. $1975):	**1983**	
Fertilizer (Mill. m.t.):		**0.93**
Fertilizer Cost (Mill. $1975):	**273**	
Return to Capital/Land (Mill. $1975):	**2694**	
i.e. 54.4% share		

***Numbers in parentheses show level of excess production: for example, the production of roots is 10.8 times the domestic requirement.**

5.8.2.4. Estimate of input requirements

Table 5 gives an example of the input requirements for the intermediate and high input levels. These requirements can be "matched" to the resource availability and appropriate agricultural input policies can be formulated.

5.8.2.5. Estimate of land degradation hazard

Table 6 shows the effect of degradation on the availability of land, under the assumptions of the presence or absence of conservation measures, for each of the three input levels and present crop mix constraint. The results show that degradation would lead to a substantial loss of total

TABLE 5 Input requirements in the Kenya case study.

	Area (1000 ha)	Power (man-year equiv. mill.)	Fertilizer N–P–K (1000 m.t.)	Conservation (man-year equiv. mill.)
Intermediate Input 60% Conservation PC Mix/Max. Food	2377	8.7	111	0.8
High Input Conservation Max. Food	4326	11.3	941	1.5
1975	2300	2.2	65	n.a.

2000 Rural Labor Force 11.2 million

agricultural land and, in particular, of the more productive land classes. For example, depending on the level of inputs, 61% to 77% of the very high and high productivity land would be lost in the absence of conservation measures. Note that the national level estimates of land degradation, in Table 6, are available by location (regionalized) in the country. This information is useful for identifying the critical areas susceptible to soil erosion in the context of the agricultural crops and input levels.

TABLE 6 Degradation hazards and land productivity: national land area (1000 ha) by productivity class.

	TOTAL	VH	H	M	L	RANGE LAND
PRESENT CROP-MIX WITHOUT CONSERVATION						
LOW	1871	53	187	381	1250	26117
INT.	2407	106	374	526	1401	26156
HIGH	3700	197	477	791	2235	22700
WITH CONSERVATION						
LOW	3612	310	744	659	1899	24366
INT.	3882	442	814	947	1679	24374
HIGH	4850	614	1112	1269	1855	21027

5.8.3. Policy Relevance

The data and information generated in this study are useful for many aspects of agricultural development planning. The present results should be regarded as a first approximation. The Phase 2 Kenya study (based on the 1:1 million soil map of Kenya, i.e. a basic land unit of 400 ha) will be more realistic, and even at this level further field analysis will be necessary to validate the results. The policy use (Kenya, 1979) and implications of the study are numerous.

5.8.3.1. Soil erosion and conservation policy

The study generates data on the location of areas where soil erosion may be critical. For a particular area, the analysis provides information on what crops and input levels would reduce the level of soil erosion. The identification of the area susceptible to soil erosion and the conservation measures necessary can be linked to government policy on incentives, public works and employment for conservation.

5.8.3.2. Migration and food distribution policies

The study identifies areas of potential production as well as areas which are or will be critical (the resource base cannot support the resident population). Policies on outmigration and/or alternative development are relevant here.

In contrast to outmigration, when the land base cannot produce the local food requirement, is the creation of alternative employment opportunities and the transfer of food from surplus areas. The latter aspect will necessitate investments in transportation, additional food storage capacity and infrastructure development.

5.8.3.3. Domestic food demand and trade policies

Relative prices, shifts in traditions, the marketing system and development have largely been the causes of changes in the domestic food demand (Shah, 1979). For example,the demand for sorghum and millet has declined while the demand for wheat has increased. Does Kenya have the natural resources (climate, rainfall, and land) to satisfy the increasing domestic demand for particular food crops? The results on potential production of individual crops can be incorporated in domestic food policies to "push" (increase demand) for crops with high production potential and to "pull" (decrease demand) for crops with low production potential.

In the past export trade has been concerned basically with nonfood crops. The potential production of some cereal crops, roots and livestock products suggests trade possibilities. The methodology permits an evaluation of this type of issue.

5.8.3.4. National game parks policy

In Kenya there are some 30 national game parks and 21 proposed national reserves. This land area amounts to 11.7% of the total land area. Many of these parks and reserves are situated in marginal areas; however, some areas have considerable agricultural potential. At 1978 producer prices, the value of potential food production from national parks and proposed reserves has been estimated (Shah, 1980) to be 83.7 million and 20.1 million Kenya pounds (1 Kenya pound = US $ 2.8).

Kenya is committed at present to preserving its wildlife heritage – the heritage of mankind– but will its population in the next century be forced to reassess this commitment?

5.8.4. Concluding Remarks and Further Work

The assessments of food production, degradation hazard and population-supporting capacity have been discussed in this paper. The Phase 1 results should be regarded as a preliminary first approximation. At present, work on Phase 2 and Phase 3 is in progress, and this is scheduled to be completed by mid-1982.

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PART 6. PLENARY SESSION: INVITED COMMENTS

Professor Rübensam (*President of the Academy of Agriculture Sciences of the German Democratic Republic and member of the Advisory Committee to the Food and Agriculture Program*):

The Status Report Conference of the Food and Agriculture Program has made it quite clear that the problems discussed and worked on at IIASA have been meaningful, and that first results are available. This conference not only gave ideas for future work, but it also conveyed a series of very valuable suggestions to all participants. We would like to express our heartfelt appreciation for this work, in particular to the Director of IIASA, Dr. Levien; to Professor Rabár; to Professor Parikh; and to all those who presented their work.

Please allow me, as a member of the Advisory Committee, to put forth some ideas and suggestions. First of all, this conference has confirmed that the Food and Agriculture Program is a really complicated project. It is a very far-reaching objective to work out really effective solutions in order to overcome hunger in mankind, while taking into consideration the limited resources and environmental impact of agricultural production. Secondly, this conference showed that the interests of the National Member Organizations of IIASA are different, but it simultaneously showed that the joint work of finding solutions need by no means be hindered.

Therefore, it is to be endeavored – beginning with the objectives – to place in the foreground the common concern and at the same time not to neglect the different conditions prevailing in different countries, because ways of achieving solutions will differ accordingly. We should not overlook that in general this has not yet been fully accomplished. For instance, in the speeches delivered the word "prices" was mentioned at least one hundred times more often than "intensification of production." Of course, no one will underestimate the importance of proper prices and distribution of foodstuffs. However, without raising production – especially in the developing countries – hunger will not be overcome.

Surely it would be superfluous to continue a very detailed discussion of the relationship between Tasks 1 and 2. However, it seems absolutely necessary to focus more on the problems of technology, resources, and environment – including the problems of optimization, and of reducing as much as possible the expenditure of energy per unit of food production. This has been pointed out in a number of presentations here.

In this context we have missed the presence of responsible staff members of those areas at IIASA which have close connections with, and which are partially financed by, the Food and Agriculture Program. Obviously the possibilities and opportunities for integrating the work of different areas have not yet been advantageously utilized, although this is a justly recognized advantage of IIASA.

In future work the common efforts should be focused more on defining more clearly the objectives of the whole Food and Agriculture Program – of both Task 1 and Task 2 – especially as they concern scientific strategy and realizable ways of solution. And we think it purposeful to include and integrate the policy makers of the participating countries in the definition of the objectives at this stage of the program and not to confront them at the end with the results. The arsenal of methods of systems analysis should also be used more extensively, as was presented here in the US model, the most successful application to date. The experiences gained in the elaboration of the Energy Systems Group here at IIASA should be useful to FAP, especially so far as approach is concerned; in other words, a concrete point of departure could be the estimation of demand over the next two to five decades, and the discovery of possibilities for meeting this demand.

On the whole we are of the opinion that this Status Report Conference conveyed very valuable impulses and stimuli for future and even better realization of the tasks which put great demand on us and which we have put commonly as the goal towards which we work – making an effective contribution towards overcoming hunger in the world.

Dr. Hrabovszky (*Senior Policy and Planning Coordinator, Agriculture Department, FAO, Rome*):

I am happy to be able to summarize what I have learned over the last two days and what one may be able to distill out of these impressions as a guide towards the future.

It's not easy. I would like to repeat Professor Rübensam's statement saying how complex a problem this is and how carefully one has to approach it. I would also like to add that, although it is one phenomenon, it has very many different aspects, and each of these is in itself worth studying. So we should not feel unhappy that some of us value certain aspects of the problem above others. I think these views should be able to live side by side with each other; each of them is contributing to the solution of a central, complex, and difficult task.

I would like to mention a number of points. The first is that it appears to me that linkages already exist in a number of ongoing or completed projects between Task 1 and Task 2. Let me just cite two very obvious examples. The Thailand/Bangladesh model has a very explicit coupling system between the concerns of the two tasks. Maybe the Task 2 component of the model is not so fully developed as the champions of Task 2 would like, but there should be no major difficulties in extending it. The other example, the Hungarian Task 2 model, clearly intends to operate within the larger framework of a national economic model of Task 1. These are possible ways of meaningfully relating the two tasks.

To evaluate what kind of additional work would be needed to make possible this linkage between existing models, I think there is a need carefully to assess the present models. In some cases, IIASA should feel free to have a specific Task 1 model too far away in detail to be meaningfully linked with its corresponding Task 2 model. In other situations it should clearly be attempted to bring both models together. What I'm trying to drive at is that linkage between tasks should not be a religious fetish but a useful tool. If it can be accomplished within reasonable constraints and within the target systems of the organization, then it should be done; but it should not be elevated to the level of a dogma.

Another comment in this area is that the approach taken in Task 2 is meaningful, well defined, and flexible, and will go a very long way towards being able to retain the mainly physical, biologically oriented main message of these models and to move towards a better understanding of those phenomena in the systems. At the same time the decision making module, which sits there – a little bit to the side but as a part of the whole – could provide very meaningful linkages to Task 1.

My next comment refers to one of the means of bringing together these two tasks in a practical manner. If I may make the following point, I personally would like to see more people like myself in Task 2. I am a physical planner, an agronomist by basic training. I used to be a farmer, and physical, biological relationships are very important for me; this is my daily bread. But I also recognized that being able to talk with economists, to deal with their issues, makes my own knowledge much more useful. At the same time, among economists there should be a great willingness to learn from technical specialists, to see the setting of a problem sometimes in a physical, technological sense, and then to put it into the superstructure of economics. If this kind of person-to-person multidisciplinary or interdisciplinary approach is built into the teams, then we will see many problems dissipate that may have loomed large in the past.

A further point is that one of the central difficulties in Task 2 will definitely be the issue of aggregation versus disaggregation. At what level do you visualize the basic analytical unit? I think in this situation we must be good economists. We should try to the best of our abilities to weigh carefully the gains and losses, marginal costs, and marginal returns of moving up on the aggregation scale. Now, this is not an easy task, as I know myself, because in my own daily work I have fights about it. In general, technical specialists wish to go into much more detail. On the other hand, economists would like to aggregate as high as the sky, because it is much easier. Usually people who work with models would also like to see the number of variables reduced. So there are three groups of people, each of them fighting for a different level of aggregation. Decisions concerning the level of aggregation should be made after weighing the cost involved against the returns of a particular level. Therefore, try to see a cost course and a return course on that aggregation dimension, and try to make decisions accordingly. When we work in a discipline, we think we've found the appropriate level of aggregation to do the work. Try to step back from this situation and look at it as a decision making situation, and try to give some weight to different views on this within the team.

I'm reluctant to make any further comments on Task 2, especially in the light of the warning given to us by Kirit Parikh that we shouldn't add to the burden, we should lighten it. I still think that all the talk on Task 2 up to now was about crops and not a single word was mentioned about livestock. In developed countries livestock makes up about 50% of output; in developing countries, around 25%. I think that Task 2 ought to take this into careful consideration. There can be no question about it: modeling livestock is much more difficult than modeling crops. I know it because right now my main job is to build a livestock model. So I would very much like to discuss this in detail with the team to see how the efforts that we are making could be useful to FAP in some form or other.

There have been some issues raised in our discussions on the role of analyses of developing countries in IIASA's model-building effort. One of the major outputs of most of IIASA's work, especially in Task 1, would be finally to arrive at world-level pictures. However, you cannot paint these pictures without including a sound component for developing countries. Very often the behavior and the situation of developed countries or groups of developed countries will depend on what is going to happen in the developing countries.

Finally, I would like to raise the flag of Task 3 by picking up Glen Johnson's comments and my own, by saying – in spite of Professor Parikh's statement, "Please do not shove too much additional work on us right now" – that the institutional, the human, and the research policy aspects clearly belong in the system. It is perhaps possible to build Task 2 and to finish Task 1 in such a way that wires will be left dangling onto which Task 3 will be able to hook. This may be a worthwhile thought to keep in mind.

Professor Nazarenko (*Director of the All-Union Research Institute of Information and Technical–Economic Research in Agriculture, USSR*):

Allow me to say a few words about my understanding of the work of the Food and Agriculture Program here at IIASA and our hopes and beliefs in future activities in the field.

First of all we note with satisfaction quite substantial progress in the development of national food and agricultural models for several countries in Task 1. I believe this is the key point in Task 1 – to develop really substantial and realistic nationwide models for food and agriculture which eventually can be linked in some sort of worldwide food and agriculture model. One begins from the background, with the soil, to develop a national model, and afterwards to aggregate these models to some extent in regional and worldwide modeling. In this case, I believe that the national models, as we have seen in the last two days, can be quite different starting with each specific country. In countries such as the Soviet Union they have a more or less complicated, sophisticated economy; and they believe that a national agricultural model cannot be limited only by the traditional agricultural industries but should also include – as they call it – an agroindustrial complex or food complex of the national economy. In this case the model should be more broadly based and should include all industries engaged in food processing and distribution. I believe that such a broad-based approach to modeling can be of use in the development of Task 1. This type of modeling – including very different types of economies – should be done very carefully and not only should be based on statistical estimation but also should include some sort of qualitative analysis which takes into consideration governments' programs and other political decisions. I believe that such national models, subsequently linked to some extent internationally, can be of use and should be the basis for Task 1.

We in the USSR are very eager to participate in Task 2. In the rather large area of Stavropol, in the North Caucasus, we have just begun a case study which may be considered as a kind of pilot project; and similar studies can be developed in other areas of the country in a manner related to work done at IIASA. In methodology concerning, among other things, the development of a farming system to help decide the nature of crop mix, livestock, alternatives of labor and capital use, and so on, our case studies could also be connected with FAP Task 2.

Among the most important problems in Task 2 are not only how to develop a rather sophisticated and complicated model, but also how to obtain a really sound data bank. The key point is how to acquire complete information concerning the quantitative technology which can be used in modeling. In very many cases this is a limiting factor on the development of the types of models which we would really like to have. One should – and I believe that the staff of IIASA share our belief – create here at IIASA a data bank which includes not only the traditional statistical data from FAO or other international or national agencies, but also quantitative and maybe qualitative descriptions of modern or traditional technologies, not only existing ones but also likely future ones. These technologies can and should be used in our modeling of Task 2. We would be eager to supply all the information we have in our country, particularly from my own institute, and to deliver special technical reports to IIASA. An alternative would be to develop a special questionnaire, which could be distributed to countries participating in the projects, with a standard format such as those used in Eastern European countries, for instance, to describe a technology step by step using traditional standards and norms. I hope that this task of developing a data bank, useful for both tasks of the FAP and including not only statistical but also technological data, receives contributions and support not only from the very limited number of people who are actually engaged in this work here at IIASA, but also from the whole network of collaborating institutions, including our institutions, FAO, other international institutions, and national agencies supporting our program. This data bank could be of use to all of us. We could develop a network for collecting the data for this data bank and at the same time develop a system for exchange of data in order to make these data available for common use by all agencies, institutions, and countries which participate in this project.

Professor Heady (*Director and Distinguished Professor of the Center for Agricultural and Rural Development, Iowa State University of Science and Technology, US*)

I would like to commend the staff and management of IIASA for having planned and implemented a very successful Status Report Conference, the most meaningful and useful one that I have attended. I've received great gain out of it, and I'm sure other delegates and participants have done likewise.

I see progress being made. The specification of Task 2 is much clearer now and more obvious in terms of its nature and the vastness of the task to be done. I also thought that a better relationship between Task 1 and Task 2 was specified at the meeting. An indication was also made of the great work to be accomplished in linking these two stages.

I am impressed with the participation at this meeting. I think that up to this time IIASA has served more to promote technological transfer among developed countries, and now we see taking place more of a transfer between developed and developing countries within the restraints of financing and the Charter of IIASA. I would like to see this continue; it could be one of the more important directions for such transfer to take place, and it's a very important aspect of the whole program.

You are engaged in a very complicated set of activities; the problems being tackled are complicated, the work being done is complicated. The work and the complexity of the problems both involve a long-term planning horizon. Unfortunately, the staff at IIASA is a short-term staff, and the very important accomplishments within this setting take place, I think, through the more or less permanent involvement of groups from outside IIASA.

By working hard, Task 2 will have things going by the end of the summer. We would find it very useful if there could be communication among all the teams working on Task 2 – not just an occasional conference such as this, but periodic communications so that we could keep abreast of the problems being encountered by the others, so that we could pass on the problems we are encountering, and so that we could see how others are tackling the tasks in which they are engaged. It could be an activity which has broader scope than it seems.

For our own activity in the United States we have a national planning committee. The purpose of this national planning committee is to see that our national model has applicability to the different regions of the United States. This is one reason why the regional aspect is so important to us. We would like to be able to take these experiences from IIASA to our national planning committee, which then might have more of a basis for improvement and guidance of our own work.

Professor Bowman (*Director, Centre for Agricultural Strategy, Reading, UK*):

I realize that my comments may perhaps be construed as criticisms; however, I wouldn't want what I'm going to say to be construed in that way. I would like to emphasize that what I've gained from my stay here is an impression of a program which is very much ongoing and is very well designed to achieve the long-term objectives. So the suggestions which I have are results of having been here these three days and for one or two previous short visits.

The first point I want to make relates to comments which Professors Rabár and Parikh made in their opening talks. They pointed out that on the one hand we have an increasing world population and on the other we have sufficient food to go around. They pointed out that the real problem was maldistribution – maldistribution internationally and maldistribution within countries. Now I am left with the question of to what extent the models tell us anything about maldistribution and in particular what the models are going to tell us about maldistribution of food supplies within countries. The international market economy probably handles in some way – though clearly not satisfactorily – the maldistribution between countries. But we need to do other things within countries to try to sort out these internal maldistributions. I'm not at all sure that the models in their present form tell us anything about that particular problem. And yet, our two opening speakers focused on maldistribution as being the major problem that we face in the short term – not the need for an increase in production, or the problem of trying to cope with many more people.

Now my second point is very much an echo of something that Dr. Hrabovszky said. For the past five years I've been working in a center in which we have been facing national problems and in which the people have come from a variety of disciplines – from economics, from technology, and from sociology. Thus, I am a little bit worried about the split between Task 1 and Task 2. I would suggest trying to find economists and technologists who are prepared to work with each other – sympathetic technologists, sympathetic economists. My last five years' experience of trying to find a common language between the two suggests to me that it is a worthwhile attempt. It is very difficult and it does lead to frustrations, but it's a very necessary part of trying to integrate and get the best out of Task 1 and Task 2.

In regard to Task 2, a very brief point in passing: we've recognized that undernutrition in the developing world is a problem. We perhaps also ought to recognize that overnutrition is a problem in developed countries, and we ought to take some recognition of the relationship between diet and the health of the population.

My third point concerns timber and energy. I want to echo, though not necessarily entirely to agree with, what Dr. Ferguson said. To leave out the problem of timber supplies is to ignore a very important effect on the FAP. Rather than corn or sugar cane, timber may well be the most suitable form of biomass for fuel production. Supplying timber for heating, for cooking in the developing world, for structural uses, for material uses as well as for fuel uses: certainly from the beginning of the next century this is going to take a lot of land. We ought to recognize in the FAP that a lot of land needed for timber will not be available for increases in food production. I would query whether there is sufficient linking of the effects of a need for increased tree planting on the availability of land for food production.

My fourth and final point concerns draft animals and subsistence farming. In the presentations it was pointed out that these topics would be included in the country models. But here again, will the overall model in fact be sufficiently responsive, sufficiently flexible to take account of the consequences of what might happen to subsistence farmers and what might happen in terms of the need for providing feed for draft animals in countries where mechanization is not very far advanced and may not be appropriate? It's interesting to recognize that the increase in agriculture output in the United Kingdom in the first half of this century was largely a result of replacing horses with tractors. The land that became available as a result of not having to feed the horses was what made possible the increase in agricultural output.

Dr. Rossmiller (*Foreign Agricultural Service, US Department of Agriculture*):

First, it seems to me that the linked system that has been developed needs to be tested, tested, and tested. You don't know what you have until you have started using it in a series of runs that focus on particular problems, particular issues. The simple analyses reported yesterday by the EC group and the US group seem to me to have revealed some of the strengths and some of the flaws in the linked system. A much wider array of problems should be posed to those models. The problems should be chosen to test and to stretch the conceptual limits of the models to determine whether the conceptual basis is sound and adequate. It is necessary to be able to analyze and rationalize why the model performs as it does, and the only way to do that is to test it, test it, and test it again.

Second, I have some reservations concerning Task 2, first of all with its conceptual base and then with the appropriateness of linkage with Task 1. I'm probably a bit of a heretic in this regard. Task 2, as I see it, can be extremely data- and resource-intensive. The explanation of Task 2 and its expected output seems a bit fuzzy to me. Until the objectives are fully and tightly defined in an operational way, the magnitude of the data and resource requirement will not be known. Until that is done it's necessary to keep flexible about how far you want to go with Task 2 and what the nature of Task 2 ought to be.

With respect to the nature of the linkage of Task 2 and Task 1, I fail to see how the two can be formally linked across the board. I think I would agree with Dr. Hrabovszky that the pragmatic solution is probably the best. If in fact there is a natural link in some countries, by some teams, and by some components, fine; but if there is not, don't force it. However, what seems to be most useful in Task 2 is some of the conceptual base, which could be incorporated directly into some of the national models in the linked system.

Third and last, I am pleased to see that there are a number of representatives from other international organizations at this conference. Certainly the long association between IIASA and FAO is well known. I noticed that there are representatives from UNCTAD, from UNIDO, and from the World Bank. Orhan Güvenen is here from the Data Processing and Statistics Directorate at OECD. I am, however, very disappointed that there seems to be no one here from the Agricultural Directorate at OECD.

There are finite amounts of resources available for this kind of activity to our countries and to the international organizations of which our countries are members. This means that we really have to husband these resources and to specialize to some extent. FAO has provided most of the data that has been used by IIASA in these models. IIASA has modeling skills that probably no other international institution has. OECD has the links with policy makers in the OECD member countries. There should be a much tighter link between IIASA and institutions like the OECD in order to make the work of the FAP relevant and useful to decision makers. This would be what almost everyone in this room would like to see. In a specific way this raises a very important point that IIASA probably needs to start thinking about. You're almost on the verge of having a potentially useful product. If that product is going to be used, then you have to make some decisions about how you are going to merchandise that product, how you are going to extend it, and what kind of an outreach program you'll have. Will you be passive and wait for others to come to you? Will you be active, and if active, where will you be active? Should the Food and Agriculture Program's output be disseminated beyond the cooperating Food and Agriculture Program's network? Then to whom and by what means? I think it's time to start thinking about that question.

Professor Mordvinov (*Committee for Systems Analysis, Presidium of the Academy of Sciences of the USSR*):

Being a newcomer I am privileged in that if I accidentally say foolish things, I might be forgiven. I belong to a small group of people who are involved in work which seems to combine scientific work and practical planning. So we are trying to find ways and means to build a bridge between practical planning and the scientific work done by IIASA.

Having said that, I will give some information which might be of interest to this gathering. In the USSR the approach to long-term planning and economic decision making – that is, planning by objectives – is gaining in importance. The planning horizon in the USSR is 15 to 20 years. This means that for a number of aspects of the economy, planning targets are being elaborated up to 1995 or even up to the next century. Therefore, our goals have much in common with the goals of the FAP. This explains to some extent why we have a strong interest in the scientific work of IIASA and in particular in this program.

I might add that some of the audience may know that in the USSR we are now working on a national long-term food program involving a number of government bodies and ministries and the State Planning Committee. As we see it at this stage, this long-term program should constitute an integral part of the national long-term plan for economic and social development in my country.

From a personal point of view I would say that in general we support the efforts and the approaches of the Institute in national modeling. We also support the basic approaches taken to solve the problems of technology transformation in agriculture. Because of its growing complexity, regional modeling requires deeper, more thorough, and more careful examination and analysis, especially analysis of factors which seem to be interdependent. The problem is not only economic, social, and commercial in nature, but also political. In this connection I would associate myself with the comments made yesterday and this afternoon by Professor Nazarenko concerning the modeling of the CMEA countries as it was presented, and I would add that I personally feel that the food strategy in the CMEA region as well as in other regions – for example the African region – should aim at eventually reaching at least self-sufficiency in grain. I will not mention all food products because otherwise I would have to go into detail, which I don't want to do.

Professor Boussard (*National Agronomic Research Institute, France*):

When I first heard about your project at IIASA, I really thought that it was impossible. To have so many people participate in a collaborative project on such a difficult task as organizing the modeling of the world economy seemed to me to be impossible. You have not only made this possible, but you have been most successful in doing so.

Now I will add a few comments. I will concentrate on the validation of the model, because the results of most of the models which have just been presented are in fact politically explosive. I must warn you that you may be subjected to unfair criticism. You can defend your program and results against fair criticism, but unfair criticism may kill you. So I feel that you must be very strong and be ready to defend your model. I have personally had the experience of defending a model against unfair criticism, and it was extremely difficult. A possible way of avoiding this is to place emphasis on model validation, which should be considered as a crucial task in the FAP. I don't know whether there exists any indisputable way of validating a model. I suspect not. In any case, as Dr. Rossmiller suggested, a model should be tested in every possible way before being sold to a potential user.

Dr. Candler (*Development Research Center, The World Bank, Washington, DC, US*):

In a way the best thing that we can say about this conference is that it does provide a great deal of reinforcement to those of us who have been involved in this activity, and it is very encouraging to see how far we have come This is a very important measure of success, and I congratulate you on that aspect. I don't have any criticisms, but I do have one or two cautions.

The first of these concerns the importance of documentation. I think that we are all very much impressed with your presentations. Everybody is keen to share his/her ideas and to explain objectively what he/she has done. However, the investment in documentation is necessary so that you can think of taking a Thailand model home and plunking it on your computer. We modelers are not yet thinking in that sort of dimension; we have got our models, and we are willing to make a run for somebody else. But in terms of real communication, take it home and play with it. That's something which you might aim to be able to do in another two years.

I would endorse Dr. Rossmiller's comments about the need to validate. As Professor Nazarenko also mentioned, it's terribly important for us to remember the difference between illustrative results and policy results. I know that the people who have given us results underlined that they are illustrative. It is very very difficult, however, to prevent members of the audience from converting that into a statement which they then say authoritatively has been shown by an IIASA model. So it behooves us as professionals to remember that we should apply at least as much caution to other peoples' models as we would always insist on applying to our own.

This perhaps relates also to a need to test our models on a micro level. If we obtain coefficients which we think work at a macro level, and they don't work on an individual farm, and we can't get sensible results on an individual farm, then we have to ask why we were able to get sensible results at a macro level.

I think that the connection between the work that is being done at Wageningen in providing straight technical information and the studies of the growth process explored in the Thailand model deserves very careful attention from the people who are interested in Task 2. It is not clear, however, if the work is at the point where it's really a finished product. Yet among the things which could transform our understanding of the agriculture process it is one of the most hopeful. It's certainly an important item.

In connection with validation of our models, it's terribly important to remember the bureaucratic position of a model. It's easy to get carried away in producing a model in the university or academic environment. But in fact one of the most important features of a model – in terms of its design, how seriously it's validated, and how seriously it will have an impact on policy – is where it sits in the bureaucratic process. How the method is connected to policy makers, whether they have been involved in the original conceptualization so that the questions that interest them are included in the analysis – this is at least as important in getting models applied to national policy issues as the structure of the model per se.

I'm very glad that people from Mexico are attending this conference, but other examples of countries which have put in their own resources to develop these sorts of models are notably missing – for example Algeria and Chile. While we can congratulate ourselves on how widely we have set up the network, there is still some way to go.

Professor Maruyama (*Professor of the Institute for Socio-Economic Planning, University of Tsukuba, Japan, and member of the Advisory Committee to the Food and Agriculture Program*):

What comments I have in mind to make have already been stated by other speakers, hence I will save more time for the remaining speakers by simply saying that I would like to congratulate the Director of IIASA and the program leaders of FAP on their successful organization of this Status Report Conference.

Professor Ramangkura (*Associate Professor of Economics at the Chulalongkorn University, Bangkok, Advisor to the National Economic and Social Development Board, and Economic Advisor to the Prime Minister of Thailand*):

This is the first time that I am participating in a Food and Agriculture Program conference at IIASA. The conference is certainly impressive. I am very much surprised by the progress that has been made in FAP, particularly on the Thailand Agricultural Model constructed by Professor Tims and his colleagues at the Centre for World Food Studies, Amsterdam. My remarks will be mainly on the Thai model.

Obviously a tremendous effort has been put into the model in theoretical work, in collecting data, in data processing, and in developing the software. I first learned about this model about six months ago. At that time I was helping the National Economic and Social Development Board of Thailand, commonly known as the NESDB, to formulate a macro framework for the Fifth National Economic and Social Development Plan for the period 1982–86. In this plan poverty and agriculture are two major focal points. My colleagues at the NESDB and I wanted to build a useful social accounting matrix which would be sufficiently disaggregated in the agriculture sector; but we didn't have enough time, and so such an accounting matrix was not built. We simply used an ordinary macro model. So when Professor Tims and his colleagues came to Thailand and offered to give us their model, it pleased us very much. Last week we went to Amsterdam to look at the model in detail. I found that a real effort involving economics, linear programming, and agronomics has gone into it. Moreover, it was amazing that Professor Tims and his colleagues were able to get hold of an enormous amount of data and information, some of which I had not known to exist. The data used were also the most recent data existing at the time the work was being carried out. Since then more recent data have become available, but it is relatively easy to change the model, because the methodological work and the software are now completed.

I am definitely going to take the model back to Thailand, have it installed there, and have it improved with the latest available data. It will be used extensively.

For the first time we will get an insight into the problem of income distribution. The model contains a great deal of information on income distribution, and this will allow us to quantify the problem for the first time. It will now be possible to project the pattern of income disparity among income classes to analyze the effects of different assumptions. It will also be possible to simulate the effects of various policies dealing with problems of income disparity and with other problems.

Unfortunately, it is too late to use the model for the formulation of the Fifth National Development Plan. But it will probably be used to prepare the Annual Plan from 1983 onwards, and it will definitely be used for the Sixth Plan, whose formulation will start in about three or four years' time.

Thailand is a net exporter of food, and its agriculture has consistently achieved a high growth rate of 4 or 5% per annum over the past 20 years. But our high agricultural growth over the past two decades has come about through crop diversification and an expansion of cultivated land, while yields have stagnated. This high rate of agricultural growth has resulted in an impressive reduction in the level of absolute poverty – from 57% of the population in 1963 to about 31% in 1975. Agricultural exports have also grown drastically; but now further expansion of cultivated land is nearly impossible, and it looks as though we are going to run into trouble. Unless crop yields increase, our agricultural growth rate will remain stagnant, poverty will increase, and the trade deficit will widen.

The Thailand model has certainly come at the right moment. It will enable us to see the problems and obstacles more clearly, and it will help us to find appropriate solutions. The model in its present form will need the minor adjustments I mentioned earlier. Newer surveys are available, and maybe these should be taken into account to adjust the social accounting matrix. It will also be useful to treat separately rubber, cassava, and glutinous rice.

Finally, it will be very interesting to see, when the global linkage is completed, what effects a policy adopted by one particular country has on others. Thailand will certainly be affected by the policy changes of its competitors – such as the United States, China, and Australia – and of its trade partners – such as the EC, Japan, and Indonesia. I believe the IIASA Food and Agriculture Program is extremely interesting and useful.

Professor Johnson (*Chairman of the Department of Economics of the University of Chicago, US, and member of the Advisory Committee to the Food and Agriculture Program*):

Almost at the last moment I was asked to make a few comments, so I don't have anything very carefully prepared.

I am concerned about the importance of linking the economics stressed in Task 1 with the technology stressed in Task 2. For practical purposes it seems necessary to have these linkages in order to avoid failure in both tasks. I don't think we can carry out economic analysis without taking technology into account, and I don't think we can evaluate technology without taking economics into account. It seems to me that the linkage will have to be a very simple one which involves substantial simplification of the results of either Task 1 or Task 2, or both. In seeking balance we have to equalize the marginal costs of different kinds of development of our models, and just how to balance them against each other depends on what we're going to do with the models. We might even think of linking these two tasks in some cases with considerable technical detail and very simple economics and in other instances with considerable economic detail and very simple technology; and in some cases we'll have to do both. Anyway I don't think that we can afford to do detailed analysis on both sides; I think it would simply exceed the capacity of our resources and our computers.

On a somewhat different topic I am a bit concerned that we are not looking enough at the sources of growth in our agricultural economies, particularly with respect to the development of resources. I mentioned earlier the omission of institutions and people. Of course if we are going to have balance with respect to institutions and people, again we will have to do it in a simple way. The trade linkage that has been created in FAP seems to me to be a major international capital asset which is tremendously important to a lot of countries.

I am concerned about the long-term hope for FAP. I don't know whether IIASA can maintain it. If it doesn't, I don't know who will. I think this is a much more important question for the small countries than for the large ones. The large countries can, if they want to, develop a model and keep it operational. I don't think the small countries can afford to. It is important that the models be lodged somewhere in an international agency.

In closing I just want to say how delighted I am with IIASA as a facilitator of the exchange of ideas. It's a sort of international broker of knowledge in this area. I think we all say thanks and congratulations to IIASA. This is one of the most important things you're doing.

Professor Weber (*Professor at the Department of Agriculture and Economics of the University of Nairobi, Kenya*):

In his introductory statement, Professor Parikh mentioned that 80% of world population and world agriculture production is covered by the FAP modeling effort. But if you look at the critical areas on the world map, you will observe that only two or three countries of Africa are covered. I would say that probably only 20% of the agriculture potential in Africa is dealt with in the FAP modeling effort.

Having seen the fascinating and wonderful contribution which has been made by our colleague from Kenya, Dr. Mahendra Shah, I think that his skills and his abilities should be used to model some other countries. Because I'm now working in East Africa, my interests lie more in the countries neighboring Kenya – for instance Tanzania and Zimbabwe.

I would like to add another comment to what Professor Johnson has already mentioned. In all these countries – Africa has 50 countries – it is quite impossible to find the training component available to add to this modeling effort. And I think that if you want to study another country apart from Kenya, it is necessary that IIASA provide training for the young scientists in the program. If IIASA were to undertake to train more young

Africans, they could really contribute to the progress that could be reached by your modeling efforts.

Professor Rabár (*Professor at the Karl Marx University of Economic Sciences, Budapest, Hungary, and Former Program Leader of the Food and Agriculture Program*):

It's always rewarding to have many invited speakers, because they answer each other's questions, so it's very easy at the end. I will answer some of your questions, and Professor Parikh will answer the others, so that all of your questions will be answered.

It would have been a very cheap thing to begin with Professor Boussard's remark that he thought that this program was impossible and now he is convinced that it is possible, by saying that we thought at the beginning that it was possible and now we see more and more how impossible a task it is. It is certainly a very difficult thing to reach a consensus, if one looks at the different remarks. For instance, Dr. Rossmiller has very strong reservations connected with Task 2, but the same kind of reservations are made about Task 1 by Professor Rübensam. Professor Nazarenko acknowledges the progress we have achieved in Task 1, Professor Heady the progress that we have achieved in Task 2. So there are many similar conflicting remarks. This is also what Professor Rübensam said – that many countries with many different interests are represented at the same time, that when we look at the program from all these different angles, it seems impossible. It is possible to look at the program in many ways, but not in all the ways at the same time.

The main problem which came up in almost all of the comments was, how to connect Task 1 and Task 2. What is the relationship between them? This was mentioned by Dr. Hrabovszky and by a lot of other speakers. It is certainly very important to look at technologies with the eyes of economists and to look at economic problems with the eyes of technologists. We have been struggling with this problem from the beginning.

Perhaps it has been your impression during these three days that Task 1 was a little bit more emphasized than Task 2, that more speakers have spoken about prices than about technologies, and so on. However, there are two reasons for this. The first reason is a historical one. At the beginning of the FAP – as I showed in the first slide of my introductory talk – there were nine sentences which summarized the world's food situation. We thought that the main problem was maldistribution among countries, and that we should therefore concentrate on a more aggregated level which, however, didn't allow us to go into details as far as the technologies were concerned. We realized this, but we realized it quite late. During the first three years we were dealing with tasks such as environment, technologies, and different inputs in agriculture; but we needed some time to realize what was the best formulation of Task 2. Therefore, Task 2 is now quite simply at a different stage of development. This is one of the reasons why it may appear to be a little bit neglected.

The other reason is just an optical one. I think that if we don't mention technologies or efficiency as often as prices, it is because efficiency is generally expressed in prices. Prices and the economic setting are very important if we want to show the choices among technologies; this was stressed and emphasized by most of those who were asking about a good connection between Task 1 and Task 2. Furthermore, Task 1 and

Task 2 have about equal financial support at present. The first task is really achieving its first results and giving us all the momentum we need, while the second task is just developing.

But here I have to say a very important thing. Professor Rübensam said that policy makers should not be faced with the results of Task 2 without having really participated in the preparation and conceptualization of it. In the past two years there has been ample opportunity to participate in workshops which dealt with the definition of Task 2. Furthermore, we emphasize that even now Task 2 is not yet ready. Task 2 is still at the stage of formulation, and therefore everything can still be done in a different way. All suggestions and remarks can really be taken into consideration, and we will do so as far as possible.

As to the participation of other areas of IIASA – for instance the Resources and Environment Area – I saw Dr. Kindler sitting here, even during those meetings which might have been quite dull for him. I and some of us who presented the results were referring to our joint work. We have tried to involve the other areas of IIASA, and I think we can promise that in the future we will try to involve them even more than we have in the past.

Dr. Hrabovszky emphasized – and suspiciously often – that he understands Professor Parikh's problem of having already too much on his plate in consideration of the resources of the program; and yet he suggests a lot of extensions of the program. All that he proposed needs an immense amount of work. He spoke about the Task 1–Task 2 relationship, which we have to solve and which is one of our main problems. But including livestock and the social and institutional elements in our research would certainly be a huge amount of work. We have to look at our resources and at our real possibilities.

Professor Nazarenko asked for a much more extensive definition of the food complex, including not only food production but also food processing and the whole agroindustrial complex. This is a completely free choice for all of the countries which participate in our program. In fact, the original idea of differentiating among the countries was made with the hope that each country would develop its own production module according to its specific problems and according to its national characteristics. This can be done, and each country should feel free to do so.

The data bank for Task 2 could not be organized until we had an acceptable final definition of this task. Only then could we speak about the data bank. Because Task 2 is at a different stage of development, we don't have the same data bank for Task 2 as we already have for Task 1.

Professor Bowman made a lot of important comments when he was speaking about the maldistribution within countries which is not represented in the system. This can only be a misunderstanding of our approach. In the models of the developing countries classes are modeled separately. The shifts among the income classes and accordingly the shifts among the consumption patterns of the different classes are strictly described, as this was one of our main goals when we began the national modeling. This was illustrated in the presentation of the model for India, which perhaps Professor Bowman missed because of parallel sessions.

The nutrition problem is one to which we turned our attention two or three years ago, and we have in fact written some nutrition studies. In this field, however, we felt that we were not strong and specific enough, and we had to accept the results of the other researchers.

There was one additional important set of questions which was stressed by many of you. This concerns the validation, the documentation, and the dissemination of the models. We understand the importance of these, and during the presentations we tried to stress that these problems should be solved if we want to have an operational system acceptable to many interrelated groups.

I think I have briefly answered your questions, and I would like to return to my remark that I now feel that that this task might be impossible. But here is Kirit Parikh who is at least as optimistic as I was in the beginning. In fact, what I have seen in the last year of the development and the progress of the program under his leadership is very impressive, and all the credit goes to him for that.

Professor Parikh (*Leader of the Food and Agriculture Program*):

I think Ferenc has been far too kind, and all of us know that but for his vision and leadership and initiative we wouldn't have had a Food and Agriculture Program. What I realize is that this task has come to a stage where the interest that it generates, and the feeling of the potential of what we could do, motivate everyone to suggest more and more things for us to do. It seems to make this task really an enormous one. We really have to recognize the modesty of our resources, and we must select from the various alternatives and some of the suggestions which you have made. We will have to and we will select. This will certainly displease some of you, but we unfortunately have limited resources.

Ferenc Rabár has responded to most of the points, and I could respond to some others. However, time is short and we must conclude. But before that, I would like to say how thankful I am to all of you who have made such generous comments on the progress of this task, on the Status Report, and on what you have heard over the last few days. I would particularly like to thank the FAP staff, who really worked very hard. We all worked as members of a large extended family – including the members of our collaborating institutions – and we always worked together as one big team working towards a common goal. So I offer all of them my sincere thanks. I would also like to thank the secretariat of FAP, for their dedicated work round the clock, as you can see reflected in the number of publications that have been typed and made available in the last few days. We have had enormous support from all the rest of IIASA. The inspiration and encouragement given by the Director; the support provided in organizing this conference by Conference Services under the leadership of Caroline Goodchild; the support of Technical Services – George Lindelof, Jim Thompson, and others; the Publications Department under Bob Duis; Communications, with Robert Voll; Transportation, with Gus Hammerl; Catering, with Mr. Jambrich and Mrs. Noifall; the switchboard, the telex, and the mailing services: All of these people have made a major effort to make this Status Report, its preparations, and its functioning most efficient and successful. And I sincerely thank all of them.

Now I once again thank you most of all for coming here, for listening to us with attention, and for giving us your valuable critical and constructive comments.

Dr. Levien (*Director of the International Institute for Applied Systems Analysis*):

It's sometimes said that IIASA's motto ought to be "modelers of the world unite." The Food and Agriculture Program and the Status Report Conference of these last few days have been an excellent demonstration of the appropriateness of that motto. As Kirit has said, the work that you have seen presented is, of course, heavily contributed to by the Institute's staff. But I think that it is exceedingly important, both for this program and for the development of the Institute itself, that much of the contribution came from what we call our collaborating network. This was truly a joint effort of modelers around the world, united to achieve a common purpose. We take great pride in this, and we think that those of you in the audience who are a part of this network take pride as well.

In that respect I would like to respond to one question raised by Professor Johnson which I think is most appropriately addressed to myself and to the Council concerning the future of the FAP. As many of you may already know, we have proposed to the Council the extension of the program through 1984. We have a nominal five-year life span, which would be up this year for the Food and Agriculture Program. But with the obvious progress that has been made and the obvious necessity to continue the work in order to reap the full benefits, we have no difficulty in anticipating a continuation at least until 1984. What will happen after that is still an open question. The Institute is facing this problem at the moment with the Energy Systems Group which has reached the end of its second phase. We have come to recognize that when we have accomplished as much as we have in a program, particularly in building networks and gathering data and building a set of models, there is no useful purpose to serve in stopping it, but rather a very strong and useful purpose is to be served by organizing a mechanism for its continuation. We certainly will be doing this with the Energy Systems Group, and I expect that we will find a similar mechanism for the continuation of the Food and Agriculture Program, assuming of course that the progress continues as magnificently as it has up to now. So I don't think that one need fear for the long-term viability of these activities, as long as the program continues to show strong progress and the worldwide support that it has. To reassure you, there is no intention of the Institute to cut off such successful work which can contribute in the lines of problems that we feel are important.

I would like to make one further comment. The Council is the governing body of the Institute, and it decides how we will allocate our resources and what our resources are. Those of you who come from countries which are represented in the Institutes for National Member Organizations, it would be helpful to IIASA and the Food and Agriculture Program if you conveyed to the National Member Organization Representatives in your country your opinions, your attitudes, and your judgments about the relative importance of this work. In fact, since you are the people in your country who are most knowledgeable about this, the Council members should rely upon your information and your judgments. I hope you'll take the small amount of time it might involve to do this. It would be the most useful step in assuring the continuation and full support of the Food and Agriculture Program.

Now, I only want to thank you again for coming, for being so attentive during these three days, and for contributing as fully as you have as collaborators and commentators, as colleagues, and as friends. We look forward to the continuation of this relationship. We look forward to your further comments and contributions. If you have additional thoughts that you'd like to pass along, please feel free to write to Kirit, to Ferenc or to me. And we anticipate with pleasure the next time that you return to IIASA – or that we see you in your home countries.

PART 7. LIST OF FAP STAFF, PAST AND PRESENT,* AND INSTITUTIONS OF ORIGIN

Margaret Biswas – Biswas and Associates, Ottawa, Ontario, Canada, 1978–79 (also with the Resources and Environment Area)

Hans-Jochen Budde – Institute of Agricultural Economics, University of Göttingen, Göttingen, FRG, 1978

Harold Carter – Department of Agricultural Economics, University of California, Davis, California, US, 1975–1977

Wentworth Clapham – Systems Engineering Department, Case Western Reserve University, Cleveland, Ohio, US, 1977–79 (also with the Resources and Environment Area)

Csaba Csáki – Department of Agricultural Economics, Karl Marx University of Economic Sciences, Budapest, Hungary, 1975–79

Hartwig de Haen – Institute of Agricultural Economics, University of Göttingen, Göttingen, FRG, 1977–79

Genady Dobrov – Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev, USSR, 1979 (also with the Management and Technology Area)

Günther Fischer – Institute for Numerical Mathematics, University of Vienna, Vienna, Austria, 1974–81

Helga Frohberg – Department of Food Science, University of Illinois, Urbana, Illinois, US, 1978–79

Klaus Frohberg – Department of Agricultural Economics, University of Illinois, Urbana, Illinois, US, 1977–1979, and University of Göttingen, FRG, 1980–1981

John Graham – University of British Columbia, Vancouver, British Columbia, Canada, 1980–81

John Guise – Department of Economic Statistics, University of New England, Armidale, New South Wales, Australia, 1977 (also with the Resources and Environment Area)

Werner Güth – University of Cologne, Cologne, FRG, 1980–81

Susanne Hanson – Osgoode Hall, Toronto, Canada, 1975–76

* Scholars and research assistants at IIASA for one month or more.

Jaroslav Hirs – Research Institute for Agriculture, Economics and Food, Prague, Czechoslovakia, 1977–81

Jiri Hruby – Research Institute for Agriculture, Economics and Food, Prague, Czechoslovakia, 1977–78

Bruce Huff – Agriculture Canada, Ottawa, Ontario, Canada, 1980

Ladislav Katrik – Institute for Rationalization and Management of Agriculture, Trnava, Czechoslovakia, 1980–81

Michiel Keyzer – Centre for World Food Studies, Free University of Amsterdam, Amsterdam, The Netherlands, 1976–81

Nicolaas Konijn – Agricultural University, Wageningen, The Netherlands, 1980–81

Gerhard Krömer – Technical University of Vienna, Vienna, Austria, 1981

Roman Kulikowski – Institute of Organization, Management and Control Sciences, Polish Academy of Sciences, Warsaw, Poland, 1978–79 (also with General Research/Regional Development)

James Langley – Center for Agricultural and Rural Studies, Iowa State University of Science and Technology, Ames, Iowa, US, 1981

Johannes Ledolter – Department of Statistics, University of Wisconsin, Madison, Wisconsin, US, 1975–77 (also with the System and Decision Sciences Area)

Miloslav Lenko – Computing Research Center, Bratislava, Czechoslovakia, 1981 (also with General Research/Regional Development)

Viktor Lischenko – Institute of US and Canada Studies, Agricultural Sector, USSR Academy of Sciences, Moscow, USSR, 1978

Bozena Lopuch – Computer Institute, Wroclaw, Poland, 1978–81

Matsuji Matsuda – Shinshu University, Nagano Prefecture, Japan, 1980

Alexander Maximov – All-Union Research Institute of Economics, Labor, and Management in Agriculture, Moscow, USSR, 1980

Douglas Maxwell – United States Department of Agriculture, Washington, DC, US, 1981

F. Desmond McCarthy – United Nations Food and Agriculture Organization, Nairobi, Kenya, 1979–81

Donella Meadows – Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire, US, 1977

Johann Millendorfer – Study Group for International Analysis, Vienna, Austria, 1974–75

Jan Morovic – Institute of Applied Cybernetics, Bratislava, Czechoslovakia, 1980–81

Siegfried Münch – Humboldt University, Berlin, GDR, 1980–81

N.S.S. Narayana – Indian Statistical Institute, Planning Unit, New Delhi, India, 1978–81

Viktor Nazarenko – All-Union Institute of Information and Technical-Economic Studies in Agriculture, Moscow, USSR, 1980

Marta Neunteufel – Econometrical Laboratory, Central Statistical Office, Budapest, Hungary, 1976–81

Haruo Onishi – Institute of Socio-Economic Planning, University of Tsukuba, Sakura, Japan, 1980

William Orchard-Hays – National Bureau of Economic Research, Computing Research Center for Economics and Management Science, Cambridge, Massachusetts, US 1979 (also with the System and Decision Sciences Area and General Research/Regional Development),

Karl Ortner – Modeling and Data Processing Section, Institute of Agricultural Economics, University of Agriculture, Vienna, Austria, 1979–81

Ashok Parikh – University of East Anglia, Norwich, UK, 1980

Kirit Parikh – Indian Statistical Institute, Planning Unit, New Delhi, India, 1976–81

Robert Pestel – Federal Ministry for Research and Technology, Bonn, FRG, 1975–78 (also with the Management and Technology Area)

Leon Podkaminer – Food and Agricultural Systems Modeling Laboratory of the Polish Academy of Sciences, Warsaw, Poland, 1979–81

Todor Popov – Department of International Agricultural Trade, Academy of Agriculture, Sofia, Bulgaria, 1975–78

Alberto Portugal – University of Reading, Reading, UK, 1980

Ferenc Rabár – INFELOR Systems Engineering Institute and Karl Marx University of Economic Sciences, Budapest, Hungary, 1975–81

Sudhaker Rao – Government of India, New Delhi, India, 1976–77

Duane Reneau – Department of Agricultural Economics, Texas A$M University, College Station, Texas, US, 1980–81

Jennifer Robinson – United States Council of Environmental Quality, Washington, DC, US, 1978 (also with the Management and Technology Area)

Alexander Sarris – University of California Department of Agriculture and Resource Economics, Berkeley, California, US, 1978

Kozo Sasaki – Institute of Socio-Economic Planning, University of Tsukuba, Ibaraken, Japan, 1981

Stephen Schmidt – College of Agriculture, University of Illinois, Urbana, Illinois, US, 1975–77

Jörg-Volker Schrader – Institute of Agricultural Economy, University of Göttingen, Göttingen, FRG, 1975–77

Mahendra Shah – Faculty of Agriculture, University of Nairobi, Nairobi, Kenya, 1977–81

Igor Shvytov – Institute of Astrophysics, All-Union Academy of Agriculture, Leningrad, USSR, 1978–80 (also with the Resources and Environment Area)

Ulrike Sichra – Technical University, Vienna, Austria, 1977–81 (also with Computer Communications Services and the System and Decision Sciences Area)

Taisto Sonnenson – The Swedish University of Agricultural Sciences, Department of Economics and Statistics, Uppsala, Sweden, 1978–80

Janos Stahl – Research Institute for Applied Computer Sciences, Budapest, Hungary, 1978

Earl Swanson – Department of Agricultural Economics, University of Illinois, Urbana, Illinois, US, 1975–76

Stefan Tangermann – Institute of Agricultural Economics, University of Göttingen, Göttingen, FRG, 1977–79

Anton Timman – Organization for Applied Scientific Research (TNO), Apeldoorn, The Netherlands, 1978–79

Johannes Van Asseldonk – Center for World Food Studies, Free University of Amsterdam, Amsterdam, The Netherlands, 1980

Lea Vander Velde – Law School, University of Wisconsin, Madison, Wisconsin, US, 1977

Kornel Varga – Computer Center, Ministry of Agriculture and Food, Budapest, Hungary, 1978 (also with the System and Decision Sciences Area)

Anton Visser – Economic and Social Institute, Free University of Amsterdam, Amsterdam, The Netherlands, 1978–79

Matthias von Oppen – International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Andhra Pradesh, India, 1981

Jean Waelbroeck – Economics Department, Free University, Brussels, Belgium, 1977–78 (also with the System and Decision Sciences Area)

Anton Wagemeyer – University of Göttingen, Göttingen, FRG, 1980–1981

Dennis Warner – Michigan State University, East Lansing, Michigan, US, 1980–81

Cheryl Williamson – Harvard University, Cambridge, Massachusetts, US, 1980

PART 8. LIST OF PUBLICATIONS

The published results of IIASA's research appear in various forms, depending on the nature of the work and its intended audience:

Research Reports (RR) are the formal vehicle for reporting Institute research and are intended for broad distribution to the scientific community. All RRs receive careful review, editing, typing and printing. Research Memoranda (RM) are no longer published by IIASA.

There are three kinds of papers: **Working Papers (WP)** for work done directly at the Institute, **Collaborative Papers (CP)** for results of research done jointly with other research organizations and for proceedings of conferences and workshops, and **Professional Papers (PP)** for reporting research by IIASA members not directly related to the research program.

This list of publications includes a Serial Index of FAP publications and a listing grouped by relevant topics as follows:

- Environment
- Linkage, International Trade, World Market Equilibrium, Computational Algorithms
- Modeling
- National Models
- Nutrition and Consumer Demand
- Policy Analysis – Problem Assessment
- Technology

8.1. SERIAL INDEX OF PUBLICATIONS

8.1.1. Research Reports

RR-77-024. Food and Energy Choices for India: A Model for Energy Planning with Endogenous Demand. K.S. Parikh, T.N. Srinivasan. December 1977. 38 pp.

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WP-81-010. Estimates of the Disequilibria in Poland's Consumer Markets (1965–1978). L. Podkaminer. February 1981. 19 pp.

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WP-81-012. Exploring National Food Policies in an International Setting: The Food and Agriculture Program of IIASA. K.S. Parikh. February 1981. 42 pp.

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WP-81-016. BRAZIL 2 – Consumption. Analysis of Consumption Patterns by Region and Income Class with Emphasis on Food Categories. C. Williamson, F.D. McCarthy. February 1981. 78 pp.

WP-81-038. The Basic US Model for the IIASA/FAP Global System of Food and Agriculture Models: Domestic Utilization and Prices. M.H. Abkin. March 1981. 27 pp.

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WP-81-067. Some Comments on the Estimation of Demand Relations for Poland. Z. Pawlowski. May 1981. 12 pp.

WP-81-071. Models of Expenditure Systems for Kenya. C. Williamson, M.M. Shah. June 1981. 52 pp.

WP-81-072. Beef Sector of Brazil. A.D. Portugal. June 1981. 66 pp.

WP-81-090. Specification of a Regional–National Recursive Model for IIASA/FAP's Iowa Task 2 Case Study. E.O. Heady, J.A. Langley. July 1981. 56 pp.

WP-81-110. Efficient Use of Prices and Quantity Constraints for Control and Coordination of Linear Sectoral Production Models. L. Podkaminer (forthcoming).

8.1.4. Collaborative Papers

CP-80-001. World Commodity Model for Fertilizers – The Alternative Long-Term Prognosis of the World Fertilizer Production, Consumption and Trade on the Basis of an Econometric Model. S. Meszaros. January 1980. 94 pp.

CP-80-030. Agricultural Sector Programming Models: A Review of Alternative Approaches. R.D. Norton, G.W. Schiefer. October 1980. 41 pp.

CP-81-001. Methodology for Manpower Planning in Egypt. F.D. McCarthy. February 1981. 23 pp.

CP-81-002. Technological Factors of Cereal, Potato and Cotton Production. V. Nazarenko. February 1981. 30 pp.

CP-81-006. Food Production Potential and Assessment of Population-Supporting Capacity – Methodology and Application. M.M. Shah, G. Fischer, G.M. Higgins, A.H. Kassam. March 1981. 24 pp.

CP-81-008. The Welfare Costs of Tied Food Aid. P.C. Abbott, F.D. McCarthy. March 1981. 29 pp.

CP-81-018. New Technologies for the Utilization of Agricultural By-Products and Waste Materials. Proceedings of a Task Force Meeting. J. Hirs, editor. June 1981. 151 pp.

8.1.5. Professional Papers

PP-80-004. HYV and Fertilizers – Synergy or Substitution. Implications for Policy and Prospects for Agricultural Development. K.S. Parikh. June 1980. 60 pp.

PP-80-007. Building Technological Capability for Self-Reliance. K.S. Parikh. August 1980. 10 pp.

PP-80-011. An Efficient Software Method for Econometric Simulation. H.H. Onishi. October 1980. 35 pp.

PP-80-012. A Time-, Labor-, and Resource-Saving as well as Cost-Reducing Software Method for Estimating a Large-Scale Simultaneous Equations Model. H.H. Onishi. October 1980. 44 pp.

PP-81-005. Quality Effects in Consumer Behaviour. F.D. McCarthy. March 1981. 27 pp.

PP-81-010. Investigation of the Morphological Space of Systems Variants. V.I. Iakimets. July 1981. 46 pp.

8.2. PUBLICATIONS BY TOPIC

8.2.1. Environment

RM-78-029. A Common Framework for Integrating the Economic and Ecologic Dimensions of Human Ecosystems. I: General Considerations. W.B. Clapham, R.F. Pestel. June 1978. 23 pp.

RM-78-030. Framework for Integrating Economic and Ecologic Dimensions of Human Ecosystems. II: Processes and Problem Chains within Natural Stratum. W.B. Clapham, R.F. Pestel. August 1978. 52 pp.

RM-78-031. A Common Framework for Integrating Economic and Ecologic Dimensions of Human Ecosystems. III: Policy, Uncertainty, Analysis. W.B. Clapham, R.F. Pestel. June 1978. 23 pp.

RM-78-032. Environmental Problems of Agriculture. I: Water-Related Environmental Impacts of Agriculture at the Field Level. G.N. Golubev, I.A. Shvytov, O.F. Vasiliev. June 1978. 24 pp.

WP-79-055. Environmental Problems and the Behavioral and Policy Dimensions of Agricultural Production Systems. W.B. Clapham. July 1979. 21 pp.

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WP-79-103. Resources Technology and Environment in Agricultural Development. P. Crosson. October 1979. 57 pp.

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WP-80-016. Model Specifications for Analyzing the Role and Long-Run Impacts of Resources, the Environment, and Technological Change on the Food Production System. C.R. Taylor. January 1980. 16 pp.

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CP-81-006. Food Production Potential and Assessment of Population-Supporting Capacity – Methodology and Application. M.M. Shah, G. Fischer, G.M. Higgins, A.H. Kassam. March 1981. 24 pp.

8.2.2. Linkage, International Trade, World Market Equilibrium, Computational Algorithms

RM-77-002. Linking National Models of Food and Agriculture: An Introduction. M.A. Keyzer. January 1977. 48 pp.

RM-77-019. Analysis of a National Model with Domestic Price Policies and Quota on International Trade. M.A. Keyzer. April 1977. 96 pp.

RM-77-051. International Trade Policies in Models of Barter Exchange. M.A. Keyzer. October 1977. 30 pp.

RM-78-013. Computing Economic Equilibria through Nonsmooth Optimization. M.A. Keyzer, C. Lemarechal, R. Mifflin. March 1978. 20 pp.

RM-78-024. The Food and Agriculture Model of the International Institute for Applied Systems Analysis. H. de Haen. May 1978. 21 pp.

WP-80-009. An Outline of IIASA's Food and Agriculture Model. M.A. Keyzer. January 1980. 57 pp.

WP-80-056. Simplified National Models – The Condensed Version of the Food and Agriculture Model System of the International Institute for Applied Systems Analysis. G. Fischer, K.K. Frohberg. April 1980. 115 pp.

WP-81-009. Strategic Aspects of IIASA's Food and Agricultural Model. W. Güth, R. Selten. February 1981. 23 pp.

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PP-80-012. A Time-, Labor-, and Resource-Saving as well as Cost-Reducing Software Method for Estimating a Large-Scale Simultaneous Equations Model. H.H. Onishi. October 1980. 44 pp.

8.2.3. Modeling

RR-77-024. Food and Energy Choices for India: A Model for Energy Planning with Endogenous Demand. K.S. Parikh, T.N. Srinivasan. December 1977. 38 pp.

RM-77-027. The State of the Art in Modelling of Food and Agriculture

Systems. M. Neunteufel. June 1977. 114 pp.

RM-77-036. Dynamic Linear Programming Model for Agricultural Investment and Resources Utilization Policies. C. Csáki. September 1977. 28 pp.

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WP-81-110. Efficient Use of Prices and Quantity Constraints for Control and Coordination of Linear Sectoral Production Models. L. Podkaminer (forthcoming).

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8.2.4. National Models

Brazil

WP-81-011. BRAZIL 1 – Production. The Production Module of the Brazilian General Equilibrium Model. B. Lopuch, F.D. McCarthy. February 1981. 50 pp.

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8.2.5. Nutrition and Consumer Demand

RM-78-072.The Relationship between Nutrition and Health: The Present Situation in Africa. H. Frohberg. December 1978. 38 pp.

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8.2.6. Policy Analysis – Problem Assessment

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WP-79-116. Problem Assessment for China. M. Neunteufel. December 1979. 42 pp.

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CP-81-008. The Welfare Costs of Tied Food Aid. P.C. Abbott, F.D. McCarthy. March 1981. 29 pp.

8.2.7. Technology

WP-79-103. Resources Technology and Environment in Agricultural Development. P. Crosson. October 1979. 57 pp.

WP-79-108. The Impact of Technological Change in Agriculture on Production, Resource Use and the Environment: Towards an Approach for Ex Ante Assessment. P. Pinstrup-Andersen. October 1979. 25 pp.

WP-80-016. Model Specifications for Analyzing the Role and Long-Run Impacts of Resources, the Environment, and Technological Change on the Food Production System. C.R. Taylor. January 1980. 16 pp.

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WP-80-040. Assessment of Population-Supporting Capacities – Overall Computer Programs. G. Fischer, M.M. Shah. March 1980. 32 pp.

WP-81-012. Exploring National Food Policies in an International Setting: The Food and Agriculture Program of IIASA. K.S. Parikh. February 1981. 42 pp.

WP-81-042. Assessment of Food Production Potential – Resources, Technology and Environment – A Case Study of Kenya. M.M. Shah, G. Fischer. March 1981. 62 pp.

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CP-81-006. Food Production Potential and Assessment of Population-Supporting Capacity – Methodology and Application. M.M. Shah, G. Fischer, G.M. Higgins, A.H. Kassam. March 1981. 24 pp.

CP-81-018. New Technologies for the Utilization of Agricultural By-Products and Waste Materials. Proceedings of a Task Force Meeting. J. Hirs, editor. June 1981. 151 pp.

PP-80-004. HYV and Fertilizers – Synergy or Substitution. Implications for Policy and Prospects for Agricultural Development. K.S. Parikh. June 1980. 60 pp.

PP-80-007. Building Technological Capability for Self-Reliance. K.S. Parikh. August 1980. 10 pp.

PART 9. COLLABORATING INSTITUTIONS

Over the past five years the FAP has developed a network of institutions collaborating in attaining its objectives. It has brought together researchers from around the world to focus on common problems with a shared approach. This network of collaborating institutions has made it possible for us to pursue our ambitious targets, and its support is an extremely important element of the FAP's research strategy. The participating institutions augment substantially the resources and scientific manpower of FAP. In fact, the number of person-years devoted to our program research by collaborating institutions to date is even greater than the number of person-years contributed by researchers while on the IIASA staff.

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

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

A network has been established for successfully carrying out the task on the technological transformation of agriculture. In this task the pooling of information on a wide range of technological and management alternatives from various agroecological systems is required, and our collaborative network will play an important role in enriching our technology data banks. In addition, specific country case studies will be carried out largely by the collaborating institutions.

The establishment of this network of an international research community sharing a common approach to food and agricultural policy analysis is a significant achievement of the program, an achievement that could have been brought about only by IIASA.

The collaborating institutions of the Program Core (methodology and coordination) of the FAP include:

Food and Agriculture Organization (FAO), Rome, Italy

Centre for World Food Studies, Amsterdam, The Netherlands

International Food Policy Research Institute (IFPRI), Washington, DC, US

UN Research Institute for Social Development (UNRISD), Geneva, Switzerland

For Task 1 (Strategies: National Policy Models for Food and Agriculture) our collaborating network comprises the following institutions:

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Agriculture Canada, Ottawa, Canada

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Our network of collaborating institutions for Task 2 (Technological Transformations in Agriculture: Resource Limitations and Environmental Consequences) includes the following:

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APPENDIXES

APPENDIX A

Agenda of the Food and Agriculture Program Status Report Conference, Laxenburg, Austria, February 16–18, 1981

16 February – Monday

OPENING SESSION – WELCOME AND OVERVIEW

9:30	Welcome	R. Levien
9:45	Program Genesis and Problems Addressed	F. Rabár
11:00	Achievements and Plans	K. Parikh
11:45	Discussion	

TECHNICAL SESSION
LINKAGE AND SIMPLIFIED SYSTEMS – DETAILS AND USE

14:00	International Linkage of Open Exchange Economies	M. Keyzer
14:40	Basic Linked System	G. Fischer/ K. Frohberg
15:20	Discussion	
16:00	Policy Insights from Basic Linked Systems	F. Rabár
16:30	Discussion	
16:50	Game Theoretical Approach	W. Güth
17:10	Data Banks	U. Sichra

17 February – Tuesday, Morning

TASK 2: TECHNOLOGICAL TRANSFORMATIONS IN AGRICULTURE:
RESOURCE LIMITATIONS AND ENVIRONMENTAL CONSEQUENCES

9:00	Technology Transformation in Agriculture (Problem, Research Strategy, Proposed Analysis)	J. Hirs
9:25	Model Structure	D. Reneau
9:50	Technological Change – Alternatives and Analysis	S. Münch/ V. Nazarenko
10:10	Natural Resources – Environmental Impact	K. Frohberg/ N. Konijn
10:30	Energy–Agriculture Interaction	J. Parikh
	Case Study Approach	
11:10	US (Iowa)	E.O. Heady
11:30	Hungary	Z.S. Harnos/ C. Csáki
11:50	Kenya	M. Shah/ G. Fischer
12:10	Discussion	

17 February – Tuesday, Afternoon

TASK 1: STRATEGIES: NATIONAL POLICY MODELS FOR FOOD AND AGRICULTURE PARALLEL SESSIONS – NATIONAL MODELS DESCRIPTION AND APPLICATION

	Session A	Session B
14:00	CMEA/HUNGARY Plans and Realization in a Socialist Economy –C. Csáki	EC Impact of Alternative Milk Price Policies and Barriers to Protein Feed Imports on EC Agriculture –K. Frohberg, H. de Haen, S. Tangermann CANADA Resource and Infrastructure Constraint on the Growth of Canadian Agriculture –J. Graham, B. Huff
15:30	US Structure of US Models and Preliminary Analyses of US Gasohol and EC Grain–Livestock Scenarios –Michigan State Univ./ US Dept. of Agriculture Team	KENYA Export Cropping–What Benefits for the Small Farmer? –M. Shah CHINA A Notional Model –M. Neunteufel

16:30 POLAND
Modeling Framework for Structural Change in a Socialist Economy
–L. Podkaminer

BRAZIL/EGYPT
Subsidies for Agriculture or Nonagriculture: Implications for Consumption and Balance of Payments
–F.D. McCarthy

18 February – Wednesday, Morning

TASK 1: STRATEGIES (Continued)
PARALLEL SESSIONS – NATIONAL MODELS DESCRIPTION AND APPLICATION

	Session A	Session B
9:00	INDIA Food Distribution and Right-to-Eat Programs –K. Parikh/ N.S.S. Narayana	FINLAND Regulating Production in a Food Surplus Economy– L. Kettunen SWEDEN Structural Change in Agriculture: How to Increase Farm Size –O. Bolin/E. Rabinowicz
10:30	AUSTRIA Coping with the Milk Surplus –K. Ortner JAPAN Rice Policy for Japan –Y. Maruyama, H. Onishi K. Sasaki	THAILAND/BANGLADESH (a) Impact of International Prices on Regional Income Distribution and Export Patterns (b) Agronomic Condition in Thailand –Centre for World Food Studies, Free University of Amsterdam

PLENARY SESSION

14:30 Invited Comments
Conclusion

APPENDIX B

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