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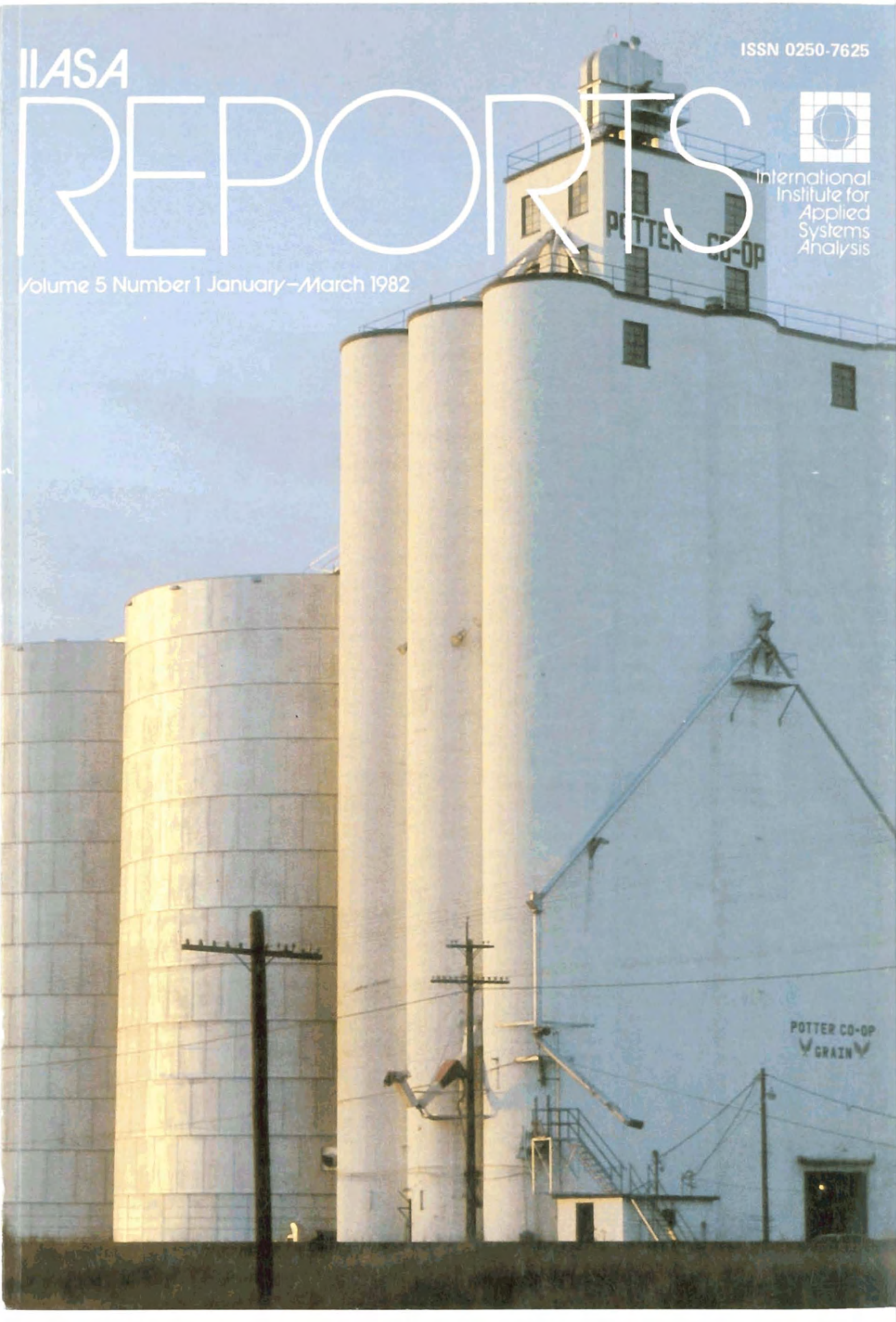

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A NATIONAL POLICY MODEL FOR THE HUNGARIAN FOOD AND AGRICULTURE SECTOR

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SUMMARY

The development at IIASA of the Hungarian Agricultural Model (HAM), as a prototype of models of centrally planned food and agriculture systems was completed at the end of 1979. The model is a joint undertaking of the Food and Agriculture Program at IIASA and three institutes in Hungary. The results of the entire three-year HAM project are summarized in this paper. HAM is a descriptive, recursive simulation model describing the Hungarian food and agriculture system as a disaggregated part of an economic system closed at the national and the international levels. The model, which will ultimately become one of a system of interconnected models, is structured according to the major elements of the centrally planned food and agriculture systems. Two spheres are differentiated within the model. The government economic management and planning submodel describes the decision making and control activities of the government. The production submodel deals with the fulfillment of central plan targets, covering the whole national economy. The general structure of the model and its mathematical description are discussed first. Two versions of HAM have in fact been produced. HAM-1 is a relatively aggregated model (10 food and agricultural commodities are considered); HAM-2 is more disaggregated (45 commodities are considered) and further refined. The two models are described in separate parts of the report, together with the results of the validation procedure and the conclusions of the actual calculations.

PART ONE

Objectives and General Model Outline

1 THE BASIC CHARACTERISTICS OF FOOD AND AGRICULTURE SYSTEMS IN THE CENTRALLY PLANNED ECONOMIES AND IIASA'S APPROACH TO THEIR MODELING

In the Council for Mutual Economic Assistance (CMEA) member countries agricultural policy and policy goals are determined by the fact that they are integral parts of the central plan for the whole national economy. The basic figures for production and consumption are fixed in the national plan and are realized by a coordinated system of sectoral (industry, agriculture etc.), regional, local (country, city etc.) and enterprise plans.

In the planning of a country's economic development the ever-increasing fulfillment of constantly growing personal demands by the harmonious growth of production is considered a basic economic requirement. The major goals of agricultural policy are therefore to satisfy consumer and industrial requirements for agricultural products, as established in the national plan. Thus the government's agricultural aims in a given period of time can be listed as one or more of the following:

- the attainment of a satisfactory increase in food production and increased efficiency and productivity in agriculture (1) by the concentration and specialization of agricultural production through the organization of large-scale state and co-operative farms and agro-industrial combines and (2) by the modernization of the whole food production system or certain branches thereof by introducing industrialized production methods and techniques;
- the attainment of a certain degree of self-sufficiency of the country in agricultural products;
- the optimization of foreign exchange earnings from agriculture;
- the improvement of the living and working conditions of the population;
- the emphasized development of food processing industries to increase the share of processed foodstuffs being produced for consumption and export.

It should be stressed that in any given period of time only a few of the above policy goals can be emphasized in any one given country. In the centrally planned countries, so-called direct and indirect policy instruments are used to realize the targets given in the national plan. In the CMEA countries, the system of policy instruments applied is generally more complicated in agriculture than in any other field of the economy.

The following list shows the complexity of the policy instruments used. The direct economic regulators of the government are for example:

- the determination of the type, size, location and schedule of the most important agricultural investments;
- the setting of targets for farm production;
- the central distribution of technical and financial resources of production;
- the determination of labor flow within agriculture and between agriculture and other branches of the economy;
- the establishment of new production organizations in agriculture.

The indirect economic regulators of government are for example:

- state pricing and price policy;
- state budget and tax policy;
- the regulation of the depreciation system;
- the control of wages and the system of personal incentives in agriculture;
- centralized credit and interest policy;
- state subsidies;
- export tariffs and import restrictions;
- exchange rates.

In the CMEA member countries the methods of handling agricultural production are not uniform. The main policy goals are similar, but methods for their realization often differ. Both direct and indirect means are applied in each country, but their roles are different. The governments in countries with centralized economic management systems operate basically by means of direct economic regulators. The state control in those with decentralized economic management systems is essentially through indirect economic means.

With respect to the modeling of agriculture, on the basis of this review of agricultural policy goals and instruments we can draw the following two basic conclusions.

Firstly, in the centrally planned economies the whole agricultural system is controlled by the national plan and the market has only a partial role determined directly and indirectly by targets for production and consumption. We therefore need a model structure different from those developed for the conditions in the market economies.

Secondly, although the major agricultural policy goals are similar, there is no unified agricultural policy in the CMEA countries as there is in the European Community (EC) countries. A country-by-country approach therefore offers greater possibilities for the modeling of this area.

2 STATE OF THE ART IN MODELING CENTRALLY PLANNED AGRICULTURAL SYSTEMS

In the centrally planned countries of Europe several models have been developed to describe the agricultural economy. These modeling efforts were strongly influenced by the existing planning system of the economy and the actual needs of the national planning bureaus and other planning authorities. Since the first attempts in the late 1950s development has taken place in three stages.

Most of the last decade can be considered the period of pioneer work. In the majority of the countries the first macromodels of agriculture were constructed then. The solution of basic methodological problems was emphasized and the work had mainly experimental and scientific characteristics. The contribution of these models to policy decisions was thus very small.

In the early 1970s more sophisticated and detailed models were built and mathematical methods became an accepted element of the techniques used for the preparation of important agricultural decisions. On the whole, however, the mathematical models of agriculture systems played only a partial role in the actual planning procedure.

Recently the elaboration and implementation of computer-based planning and information system* has begun in the majority of the centrally planned countries. The modeling of agriculture systems is coordinated with this task and the agricultural sector of the national economy is treated as one of the most important elements of this system, serving as a framework for a set of more detailed agricultural models (e.g. sectoral, regional, or by enterprise).

In most cases the modeling of agriculture has been connected with the elaboration of the national five-year and long-range (15–20-year) plans. The main objective of these models is to aid decision-making on:

- resource allocation and the production structure of agriculture;
- regional allocation of production and policy instruments (targets, prices, tax system, subsidies etc.).

The models generally cover the agricultural production sector, but models that include the food processing sphere can also be found. The remaining part of the national economy is derived exogenously. In a few cases the agricultural model was connected with an aggregated model of the whole national economy (two-level planning).

The methodology used is mostly linear programming. A deterministic and normative approach is common. Random factors (weather, world market etc.) are introduced by running the model with different assumptions. Recently multiperiod models have also been developed for long-range planning purposes. The objectives of planning efforts could be basically fulfilled by these methods. Econometric models and simulation techniques have been used only in a few special cases, but until HAM no detailed macromodels of the entire agricultural system had been completed based on the latter methods.

The most important features of the mathematical programming models developed now follow.

Agricultural production is modeled in a very detailed way. The production variables are generally differentiated according to:

- production sectors (state farms, cooperative farms, private and household plots);
- production regions;
- soil categories;
- technologies (e.g. irrigated or dry, partly or fully mechanized);
- most important crop and animal varieties.

The resource requirements are calculated under the assumption of fixed coefficients. These and all other coefficients of the models are adjusted figures that are projected based on the trend of technological development and the evaluation of the current situation. The inputs represent fertilizer, labor (annual or peak requirements), machinery, buildings, feed (according to main type) and water. The resources available for agriculture or its sectors, regions and products are mostly given in physical units. In certain cases the lower bounds of their usage are also restricted (for example, a minimum level of employment must be guaranteed for the members of the cooperative farms).

*These systems are called automated management systems (ASUs) in the CMEA member countries.

In the agricultural models consumer and industrial demand are handled exogenously. Fixed production requirements are given based on the targets for the standard of living and industrial requirements. Substitution is often permitted among agricultural products, especially foods required according to the structure of the models. Foreign trade is represented by export and import variables given separately for Western, Socialist and Third World markets. The foreign trade variables are also restricted by upper and lower bounds. The changes in stocks are modeled as well.

The models use a set of different prices (producer prices, export prices etc.). All the prices are fixed and exogenous. Most of the models contain a set of financial balances for the modeling of financial flows connected with agricultural production. The financing of investments is described in this module, and these equations have a very important role in the planning of economic regulators. The allocation of investments is restricted by a set of constraints (lower or upper bounds are given according to product(s), region(s) etc.).

In the objective function the main agricultural policy goals are expressed as:

- the maximization of the gross domestic product from agriculture;
- the maximization of the national income from agriculture;
- the maximization of the foreign balance of payments;
- the maximization of foreign exchange earnings from agriculture;
- the minimization of production expenses with a required level of production and positive balance of payments.

The experience of the previous modeling work was borne in mind in developing our modeling framework.

3 SOME FEATURES OF HUNGARIAN AGRICULTURE

Agriculture plays a traditionally important role within the Hungarian national economy. Although the share of agriculture in the production of national income has considerably decreased, agriculture still remains a very important national economic sector. An area of 6769.9 thousand hectares of land, over 70% of the total territory, was under cultivation in Hungary in 1974. Arable land represents 53.5% of national territory, one of the highest ratios in the world. In 1976 there were 2.0 million cattle, 7.2 million pigs, 2.0 million sheep and 41 million poultry in Hungary.

In 1974 some 16.2% of the Hungarian national income was produced by, and 20.4% of the working population of 10.5 million was employed in, agriculture.

The per capita value of agricultural production is higher in Hungary than in the other centrally planned countries and in certain respects it exceeds the levels reached by countries of the European Community. In 1975 the per capita annual meat production in Hungary was 140 kg, while the average for the EC countries was only 71 kg, and for the USA 109 kg. In 1975 Hungary produced 25.9% of the total corn production of the CMEA countries. In addition to satisfying to a high degree the food demands of the population (in 1975, 3242 cal and 100 g protein were consumed daily per capita), the Hungarian agricultural sector is also a considerable and regular supplier of products for export.

Agricultural products and foodstuffs represent about 23% of total Hungarian exports. For several years now, Hungary's foreign trade turnover figures for agricultural products has shown a significantly positive balance with both socialist and nonsocialist countries.

In the last few years Hungarian agriculture has developed relatively rapidly. The annual rate of development was 2.8% between 1966 and 1970 and 4.8% between 1971 and 1975.* In recent years progress has been made in increasing yields of cereals, mainly wheat and maize, and with poultry and pig breeding. The most important characteristics of Hungarian agriculture are described in Tables 1, 2, and 3.

TABLE 1 Major resources of Hungarian agriculture.

Item	1971	1972	1973	1974	1975
Cultivated area (1000 ha)	6855	6846	6853	6783	6770
Irrigated area (1000 ha)	465	485	482	482	487
Tractor capacity in 1000 horsepower	3238	3257	3342	3399	3504
Fertilizer used (kg/ha)	171	183	216	243	276
Labor force (1000s)	1167	1142	1110	1063	1039

TABLE 2 Global production of major agricultural commodities in Hungary (1000 tonnes).

Item	1971	1972	1973	1974	1975
Wheat	3922	4095	4520	4971	4007
Barley	785	807	874	899	701
Corn	4732	5554	5963	6247	7172
Sugarbeet	2023	2909	2754	3708	4089
Oilseeds	263	215	244	192	244
Tobacco	16	17	20	17	17
Potatoes	1797	1349	1355	1720	1630
Vegetables	1682	1860	1845	1962	1632
Fruits	1231	1369	1466	1472	1355
Grapes	745	844	1016	692	813
Meat[a]	1554	1626	1549	1689	1848
Milk (million liters)	1749	1756	1898	1959	1920
Wool (kg)	88	83	76	83	84
Eggs (millions)	3475	3217	3258	3628	4001

[a] All meat excluding fish.

Relatively large-scale farms are characteristic of Hungarian agriculture. The socialist sector of agriculture, i.e. the cooperative farms (including also the household plots** of their members) and state farms together are responsible for about 95% of the total agricultural production. The first cooperative farms were established in Hungary in the late 1940s, but the final organization of cooperative farms was completed only in 1961. 1742 cooperative and 150 state farms were operating in the country in 1975; the average land areas per farm were 3078 and 6327 hectares respectively.

*In the last five years 12–13% of annual national investment funds was used in agriculture.

**Household farming still plays an important role, especially in animal husbandry. In 1975 28.8% of the total pig stock and 25.9% of the total cattle stock were kept on household plots.

TABLE 3 The yields of the major agricultural commodities in Hungary (tonnes/ha).

Item	1971	1972	1973	1974	1975	CMEA average in 1975
Wheat	3.07	3.10	3.48	3.75	3.20	1.28
Barley	2.62	2.76	3.04	3.31	2.72	1.34
Corn	3.54	3.98	4.05	4.24	5.02	3.34
Sugarbeet	27.77	37.01	29.79	37.70	32.22	21.00
Potatoes	11.57	11.09	10.94	12.59	12.64	12.80
Milk (l/cow)	2354	2363	2458	2478	2446	–
Eggs (no./hen)	118	141	138	140	144	–
Wool (kg/animal)	4.5	4.7	4.4	4.7	4.4	...

State farms represent the most advanced agricultural enterprises in Hungary. Yields and average outputs surpass both the national average levels and those of the cooperative farms. Their equipment, of course, and also their assets are superior to the average in the country. Cooperative farms are organized on the basis of self-management and self-finance. Their management is secretly elected by the members. The most important decisions are taken by the members' assembly and the board of directors. The level of personal earnings depends directly on the gross income realized by the farm. As a result of this, although a certain minimum income level is guaranteed by the state, considerable differences may be found in the levels of personal earnings of cooperative farm members. The income distributions in cooperative farms as well as the increases in personal incomes are regulated by taxes.

The major agricultural policy goals are fixed in the five-year and long-range plans for agricultural development. Under the present (fifth) five-year plan (1976–80) the development of animal husbandry, in particular cattle and pig production, and the food processing industry, as well as the increase of foreign exchange earnings from the export of foodstuffs, are emphasized.* As has been mentioned, these targets are realized through the implementation of indirect economic means. The cooperative and state farms and other enterprises have a relatively wide economic independence; they are given no obligatory plan targets for their production activities.

4 MAIN FEATURES OF THE HUNGARIAN AGRICULTURAL MODEL

The major objective of the HAM project at IIASA was to develop a general modeling framework for the study of centrally planned food and agriculture systems, and to prove the appropriateness of our approach by developing a detailed prototype model. HAM is actually the first really detailed system simulation model describing the food and agriculture sector in a centrally planned country. The model is constructed according to the basic characteristics of IIASA's general model structure for centrally planned food and agriculture systems, representing a concrete example of the utilization of this framework.

The Hungarian Agricultural Model

– is consistent and comparable with other parts of IIASA's food and agriculture model system;

*The planned annual growth rate for agricultural production is 3.4%.

- incorporates the basic features of the CMEA member countries' economies;
- also describes the specific features of the Hungarian economy in food and agriculture;
- is detailed enough to be used as an experimental tool for actual planning and forecasting purposes.

As with other elements of IIASA's food and agriculture model system, in the case of HAM our main goal is not straightforward optimization, but rather to make a tool that affords opportunities for a better understanding of the dynamic behavior of the Hungarian agricultural system and the interactions of its 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 has a descriptive character. It reflects the present operation of the centrally planned food production systems and, therefore, the present decision-making practices and economic management of the government are 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 endogenize a large part of the economic environment and the most important factors of food production. The food and agriculture is modeled as a disaggregated part of an economic system closed at the national as well as at the international level. HAM therefore has the following features:

- the food consumption sphere is incorporated;
- the nonfood production sectors of the economy are represented by assuming that they produce only one aggregated commodity;
- the economic, technical, biological and human aspects of food production are covered;
- both the production of agricultural raw materials and food processing are modeled;
- all products not individually represented are aggregated under "other" agricultural production and food processing;
- financial equilibrium is maintained.

The overall methodology used in the model is a simulation technique. For the description of subsystems, suitable techniques such as linear programming, nonlinear optimization and economic methods are employed. The model is dynamic, with a one-year time increment. Subperiods within the year are not considered. The time horizon of the analysis is 15–20 years. Random effects of weather and animal disease conditions can also be considered.

HAM is constructed according to the basic characteristics of the centrally planned economies in general, and the Hungarian food and agriculture system specifically. The model therefore has certain specific features not shown by other elements of the model system. The most important specific features are as follows.

1. 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 as they are determined by the long-range development plan of the national economy.

2. According to the real structure of agricultural production in these fields, various sectors (state, cooperative, household* and private farms) are considered. In addition to agriculture, food processing is handled separately and is not aggregated with the rest of the economy.
3. In central planning, the government has a crucial role in the system. The model therefore has to include a detailed description of the government's economic management activities.
4. The domestic market included in HAM is not directly related to the world market. The effects of the international market are filtered by the government's budget.
5. Four types of prices are distinguished in the model: the domestic consumer and producer, as well as international dollar and ruble prices. The domestic prices express government policy objectives instead of being related to a certain market equilibrium.
6. The inter-CMEA trade is considered as a separate segment of the international market.
7. In Hungary the overall targets for food and agriculture are primarily realized using indirect economic means (prices, taxes and subsidies); HAM-2 therefore represents a decentralized version of IIASA's model structure for CMEA countries, where producers' decisions play quite an important role.

The major characteristics of HAM are summarized in Table 4. HAM was obviously designed to be an element of the IIASA agricultural model system under development and

TABLE 4 General features of CMEA models at IIASA.

Common features	Specific features of HAM
Descriptive	Government planning submodel
Dynamic	Various production sectors
Consumption is incorporated	Independent domestic market
Rest of the economy as one aggregated sector	Separated inter-CMEA trade
System model	Crucial role of government budget
Financial equilibrium	Special exchange module
Unified commodity coverage	

as such it will be linked with other national models and used for global investigations. Furthermore, HAM was constructed as an experimental tool for investigations connected with the development of Hungarian food and agriculture in the following ways.

- On the basis of the model, the realization of major policy goals and plan targets and their main alternatives can be investigated. For example, the key factors and bottlenecks of realization, the considerations for a faster growth, the expected labor outflow from agriculture and the feasibility of the goals may be analyzed.

*A household farm is a private farming activity of cooperative farm members, mainly around their houses.

- By linking it with other national models, HAM is suitable for studying the adjustments and reactions of the Hungarian food and agriculture system to a changing international market. For example, export and import structure, the desired level of specialization or self-sufficiency and the reaction of the domestic to the world market may be investigated.
- Finally, HAM is designed to be useful for the further development of the Hungarian economic management system, since the model can analyze the efficiency of policy instruments, the impacts of the new instruments and the areas of additional control requirements.

We hope that by developing the HAM structure and by offering possibilities for the investigation outlined above, we can contribute to the further development of the techniques of planning and economic management in Hungary. The HAM project can also be considered as an important part of the efforts for the introduction and more efficient use of computers in policy analysis and in macrolevel decision making.

5 GENERAL STRUCTURE AND OPERATION OF HAM

HAM was constructed in accordance with IIASA's general modeling principles for centrally planned food and agriculture systems. Figure 1 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 every producing branch of the national economy, including the disaggregated food production sector. The major blocks of the latter submodel are related to production, consumption and trade in addition to the updating of available resource and model parameters.

Different mathematical formulations have been used for the descriptions of various subsystems. As far as the methodology of the model is concerned, first of all our attempts to describe the agricultural policy-making and planning activities of the government should be pointed out. In HAM the implementation of given policy objectives is fully endogenized. As has already been mentioned, long-range government objectives are taken as determined by central planners. Government plan targets on food and agriculture are determined by a linear programming model. The investment decisions of the government and the adjustments of overall objectives and policy instruments are modeled by heuristic routines. This is one of the first attempts at a mathematical description of the pricing mechanism in a centrally planned economy.

The food and agriculture production is modeled according to producing sectors. The 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 separated, nonoptimization heuristic type of model block is related to the food processing. A heuristic type of model is constructed to describe the investment decisions of producing firms. The output of the non-food-producing part of the economy is calculated using a Cobb–Douglas-type function.

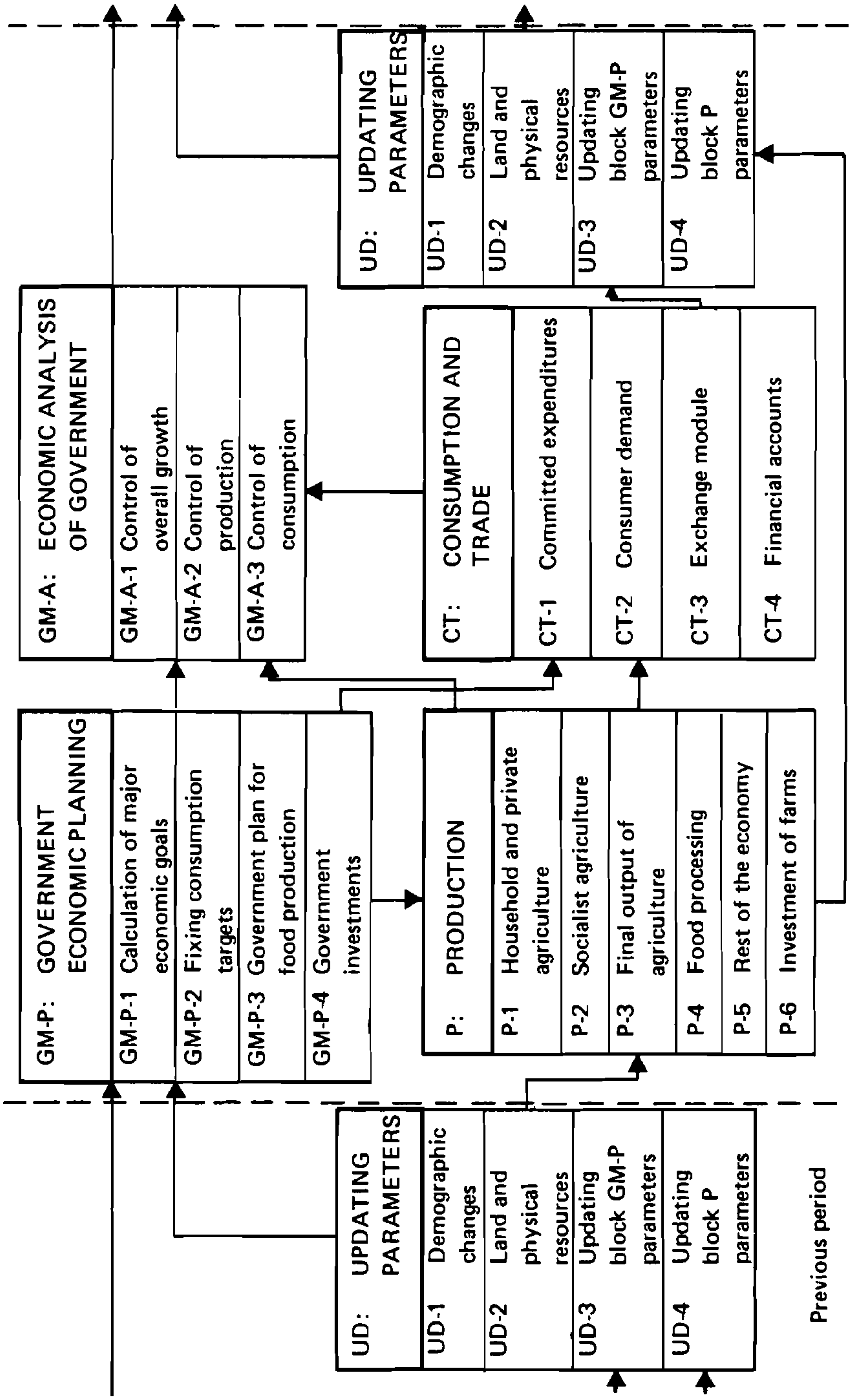


FIGURE 1 Schematic structure of the Hungarian Agricultural Model.

The Exchange module is a crucial part of the whole system. As has already been mentioned, an equilibrium type of model has been constructed to reach the balance-of-trade equilibrium and to adjust to changing international market conditions. A special version of the extended linear expenditure system has been estimated to describe consumer behavior.

The demographic changes and available resources are updated based on trend and depreciation functions. The production block parameters are actualized by using yield functions expressing the trends of biological development. Input coefficients are calculated based on production functions. The coefficients in the government economic planning module are updated based on the production block of the previous period.

The various blocks and modules of the model are interlinked through a relatively complicated system of relations and feedback loops. The major steps of HAM's solution are given in the following.

The overall objectives of the government: module GM-P-1

The first step is the setting of major economic goals of the government for a given period of simulation, i.e.:

- the desired consumption fund;
- the desired growth of the whole economy;
- the desired gross productuon of food and agriculture;
- the related indicators of total investment funds in the rest of the economy and in food and agriculture;
- the desired state of the balance of payments of the country.

These are determined based on the targets in the long range plan of the government for the desired growth of consumption, the whole economy and food and agriculture, as well as the share of food and agriculture in total investments. (The major interrelationships of the government economic planning block can be seen in Fig. 2)

Plan targets for private consumption: module GM-P-2

Based on the target value of total consumption and consumer prices updated at the end of the previous period, the planned structure of private consumption, as well as the planned total consumers' needs for individual commodities, is determined. Government objectives on the change in the consumption structure are considered and an extended linear expenditure system is used as the methodology of the calculation.

Plan for food and agriculture: module GM-P-3

The desired structure of food production (agriculture and food processing) and related exports and imports are calculated next. The desired gross output of food and agriculture (from GM-P-1) and certain minimum production requirements (based on the consumers' needs from GM-P-2) are considered as lower bounds in the linear programming model. The same applies to the required positive balance of payments from food and agriculture (also from GM-P-1). We assume that central planners want to obtain the most efficient structure of foreign trade in food and agricultural products, maximizing the net export returns on domestic production expenditures, and we use the international prices

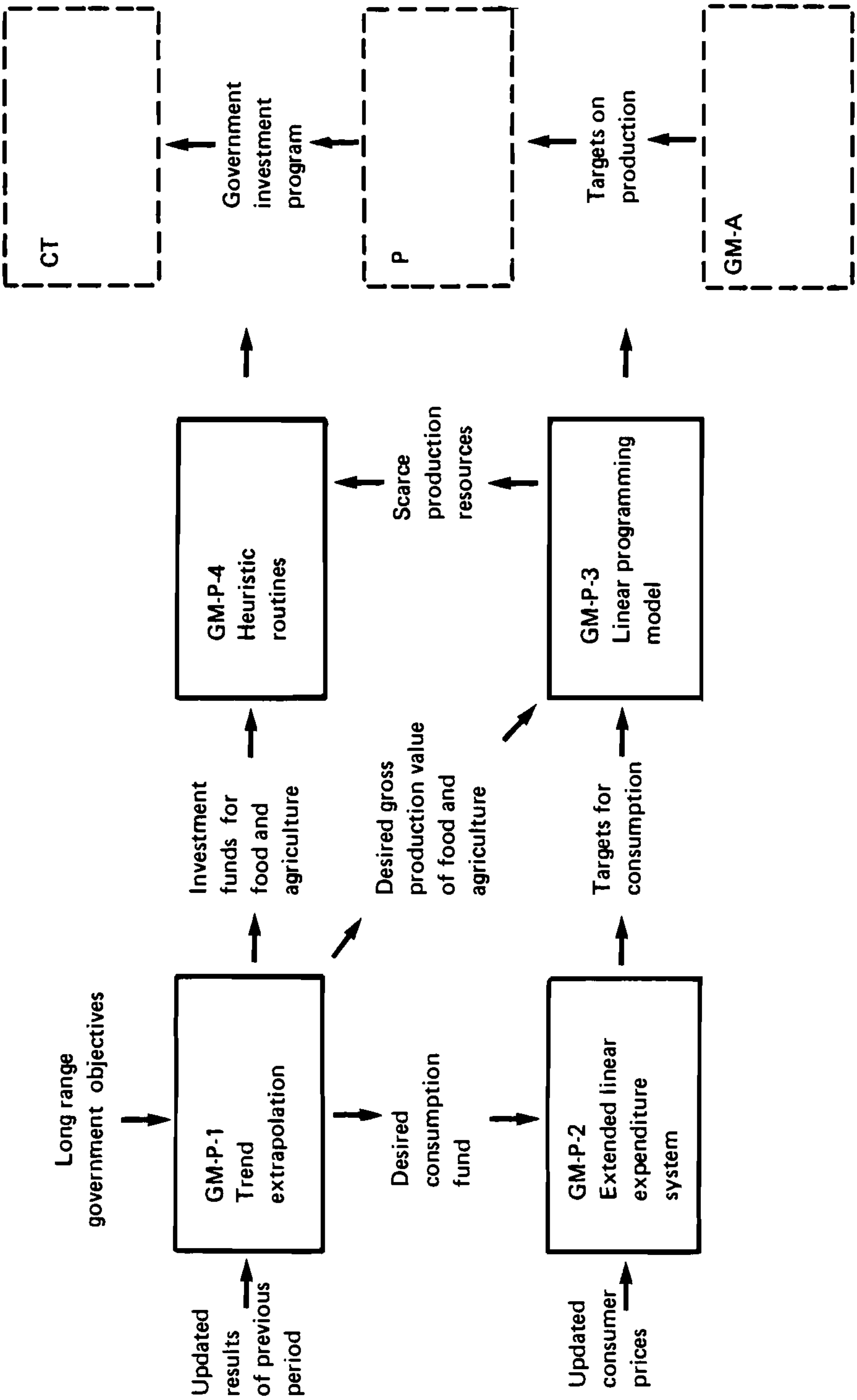


FIGURE 2 The role of the government economic planning block in HAM.

and production expenditures of the previous period. Obviously the maximization of the efficiency of foreign trade in agricultural products is only one possible goal of agricultural policy and it might conflict with other objectives. The model is capable of handling a wide range of possible objectives and has in fact been run with quite different assumptions. Upon the request of the Hungarian National Planning Bureau, foreign trade efficiency has been the focus of the first set of investigations. This model supplies the guidelines for the analysis at the end of the simulation of each year (module GM-A-1) and information on scarce resources where investment might be required.

The government's plan on investments in food and agriculture: module GM-P-4

The government's investment plan is elaborated by using heuristic routines. The investment program is settled based on the shadow prices of the module GM-P-3 solution and considering the scale requirements of various investments. In the case of food processing the decisions on new investments are partly centralized in Hungary and therefore they are modeled by GM-P-4. As far as agricultural investments and the rest of the investment in food processing are considered, only a desired program is calculated and this is used to distribute available government subsidies to firms' investments; however, the decisions on these kinds of investment are modeled within the production block.

Production decisions of household and private agriculture: module P-1

We assume that production decisions of the household and private sector are based on producer prices announced for the given period, expected yields, available land and labor force. Separate supply functions have been estimated for plant and animal production. Firstly the available land is distributed between various crops, with no constraint on labor. Secondly labor after deduction for plant production needs is used as the major limit on the volume of animal husbandry. The total amount of labor available for household and private agriculture is determined in the Updating module. The outputs of crop production calculated here might be subject to the random effects of the weather.

Production decisions of socialist agriculture: module P-2

A linear programming model is constructed to describe the decisions of socialist agricultural enterprises (cooperative and state farms) on production structure. For most of the commodities, two or three production technologies are considered and a relatively wide range of inputs to different products are taken as parameters determined in block UD. The linear programming model is structured according to resource utilization, commodity utilization and financial subsystems. The socialist sector maximizes its expected profit. The producer prices, wages and tax coefficients are given by block GM-A of the previous period. The producers' prices are not subject to changes during the simulated year, but crop yields might be influenced by the weather disturbance factor, as is household and private production. To avoid extreme solutions the change of production structure from one period to the next is constrained. These upper and lower bounds are determined based on the analysis of structural changes in the past. (The major interrelations of the Production block as well as the role of module P-2 can be seen in Fig. 3.)

Outputs of agriculture: module P-3

The final output of agricultural production is calculated in this module, based on modules P-1 and P-2. The random effects of weather on yields of annual and perennial

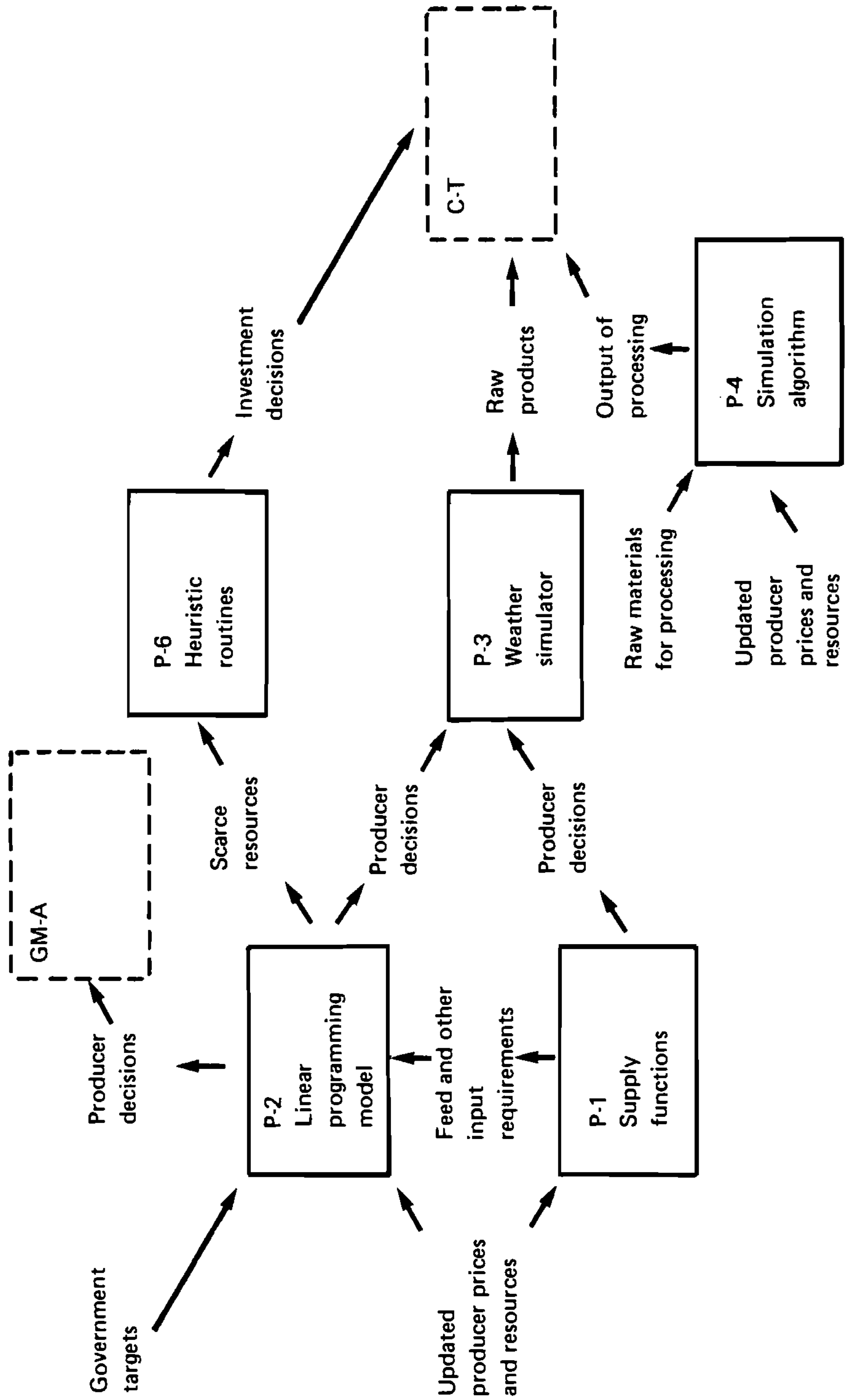


FIGURE 3 Major interrelationships in modeling food and agricultural production in HAM.

crops can be considered here. Obviously the output of animal husbandry is taken as calculated in module P-1 and P-2. If an agricultural commodity can be either processed or directly consumed, the available raw materials for processing are also determined in this module using exogenous rules and considering government preferences in the utilization of raw products (processing versus export or fresh consumption).

Output of processed food commodities: module P-4

As the outputs of agriculture are known, the output of the food processing industry can be determined. We assume that the food processing industry aims at the utilization of its resources based on a given supply of raw materials. We also assume that available fresh products need to be processed up to the level of existing capacities and also that raw materials for processing (except protein feeds) cannot be imported.

Output of the nonagricultural sector: module P-5

On the basis of the available production capacities and labor force, outputs are determined by a Cobb–Douglas type of production function. We assume that all the labor force other than that needed in food and agriculture is fully utilized in this sector. The rest of the economy is handled as one homogeneous commodity.

Investment decisions of producing firms: module P-6

The investment program of agricultural firms and food processing enterprises is determined using a methodology similar to that used in government investment decisions. The investment program is based on the shadow prices of the LP model in the P-2 module and resource utilization in the P-4 module. Scaling of investments is also considered. Obviously investments are constrained by the funds available to the firms as well as by government subsidies.

Calculations of committed expenditures: module CT-1

First of all in module CT-1 the so-called committed expenditures, which cannot be further modified, are summarized. A simple calculation takes place based on former model elements to determine:

- intermediate inputs actually used in production;
- the income and income utilization of producing enterprises (socialist agriculture, food processing and the rest of the economy) including total committed demands (intermediate inputs plus certain investments);
- the endowments and committed expenditures of the population (private consumers);
- the government's income from producers and population and the government's committed expenditures.

Modeling of consumers' demands: module CT-2

Module CT-2 describes private consumption. The role of module CT-2 is to determine the per capita consumer demands, assuming that the endowment of consumers after the deduction of savings is fully spent in buying various commodities. The consumer demands for a specific commodity are therefore influenced by the consumer prices and the level of endowment.

Calculation of noncommitted demands and exports–imports: moduls CT-3

Module CT-3 (Exchange module) is a crucial part of the entire model, where the final level of private and government consumption, as well as stocks satisfying balance of trade equilibrium conditions, are determined. It is important to note that the reaction mechanism of domestic demands to new world market conditions (prices) is described in this module.

Accounting for a given period: module CT-4

As the final results are obtained by Module CT-3 the detailed financial consequences of a given situation are calculated. This is the role of Module CT-4. (For connections in the CT Module, see Fig. 4.)

Control of the overall growth: module GM-A-1

As the next step in the simulation, the basic government policy instruments influencing the overall growth of the economy are revised based on the analysis of the performance of the whole system. From the actual growth rate of the economy the consumption fund for the next period is determined. The desired share of food and agriculture in total investment is adjusted on the basis of the growth rate for food and agriculture. Module GM-A-1 supplies the major parameters for module GM-P-1 for the forthcoming period.

Control of production structure and adjustment of producer prices: module GM-A-2

The producer's prices are changed by a comparison between the actual and the planned production. The basic principles of the procedure in revising producer prices of agricultural commodities are outlined in Fig. 5. The producer prices in food processing are revised in a somewhat simplified manner, as shown in Fig. 6. (Figure 7 outlines the basic connections of the GM-A block.)

Control of consumption, revision of consumer prices: module GM-A-3

The consumer price of a given commodity is modified (see Fig. 8) based on the comparison of the desired and the actual per capita consumption of the given commodity. During the revision, as Fig. 8 shows, relation of the consumer price to the producer price is also considered.

Updating of parameters for the next period: block UD

The final step in the simulation for one year is the updating of parameters for the next period. The available labor force and changes in population are calculated from existing demographic prognoses (module UD-1) in the same way as for basic land resources, for which the annual decrease in the amount of plowed land is taken as an exogenous parameter (module UD-2). The information for updating physical resources (module UD-2) on investments is supplied by previous model elements. The technical coefficients of production variables in the GM-P-3 module are calculated as a weighted average of the various production technologies that appear in production decisions for the actual period (module UD-3). The yield and output coefficients of the P-1 and P-2 modules are settled as a function of biological and technical development. The fertilizer usage is calculated from response functions. The other input coefficients are selected from the exogenously given set of parameters determined by experts for each technology considered and for each level of output (module UD-4).

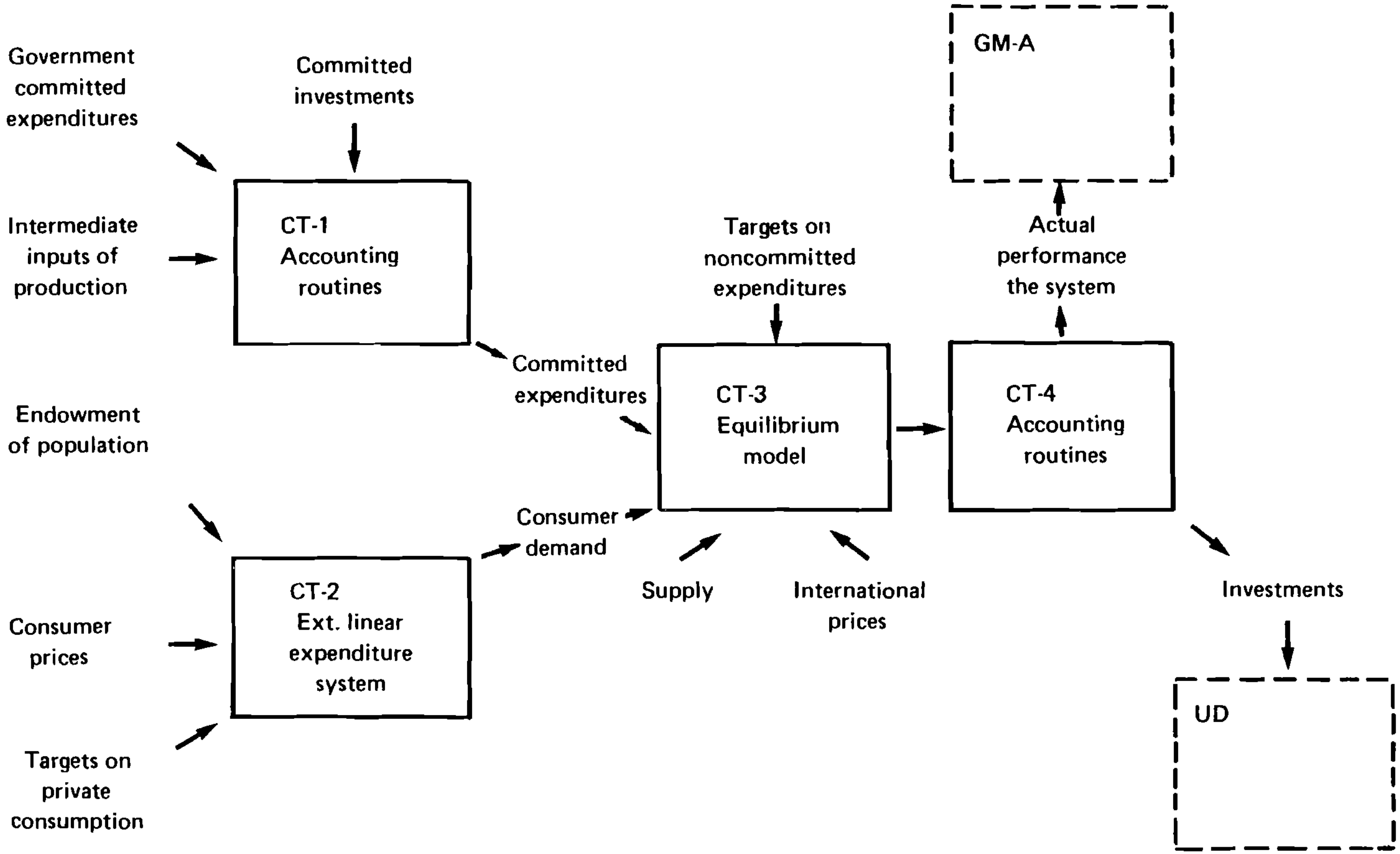


FIGURE 4 Major interrelationships in the consumption and trade block of HAM-2.

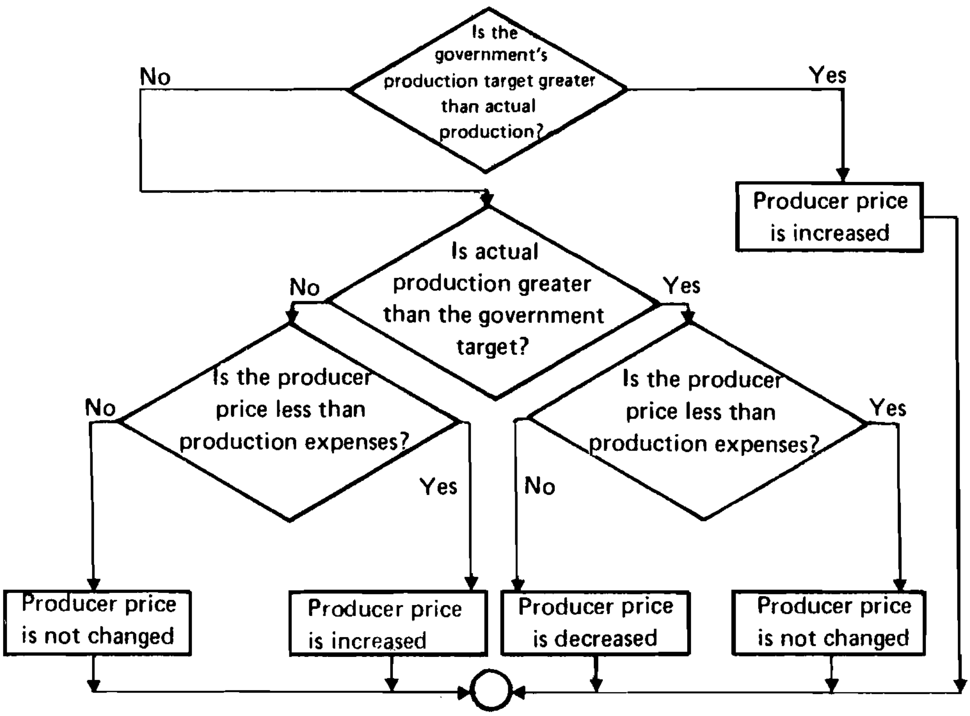


FIGURE 5 Adjustment of producer prices in agriculture.

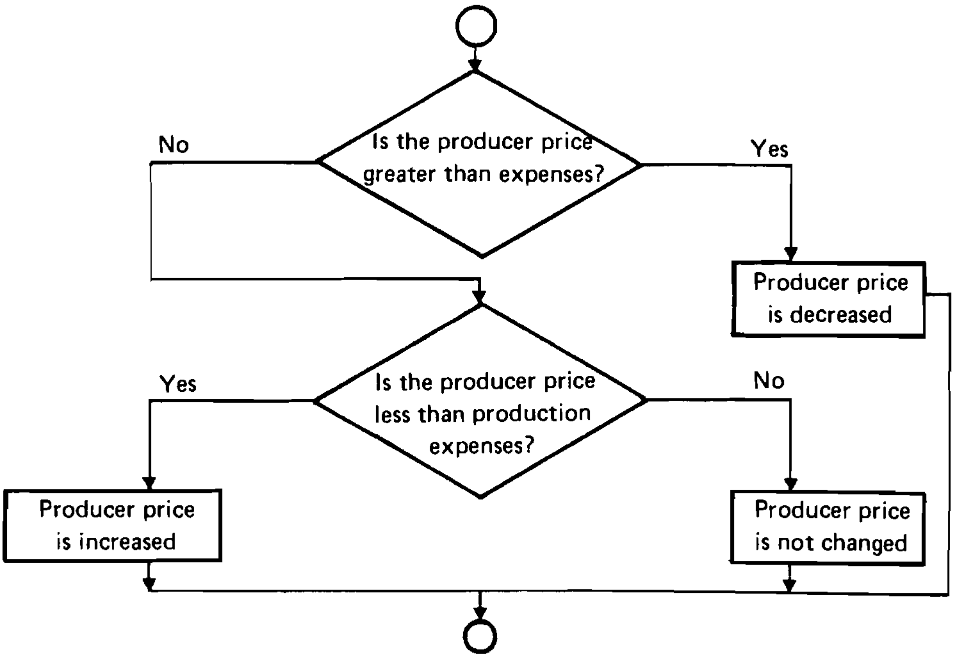


FIGURE 6 Adjustment of producer prices in food processing.

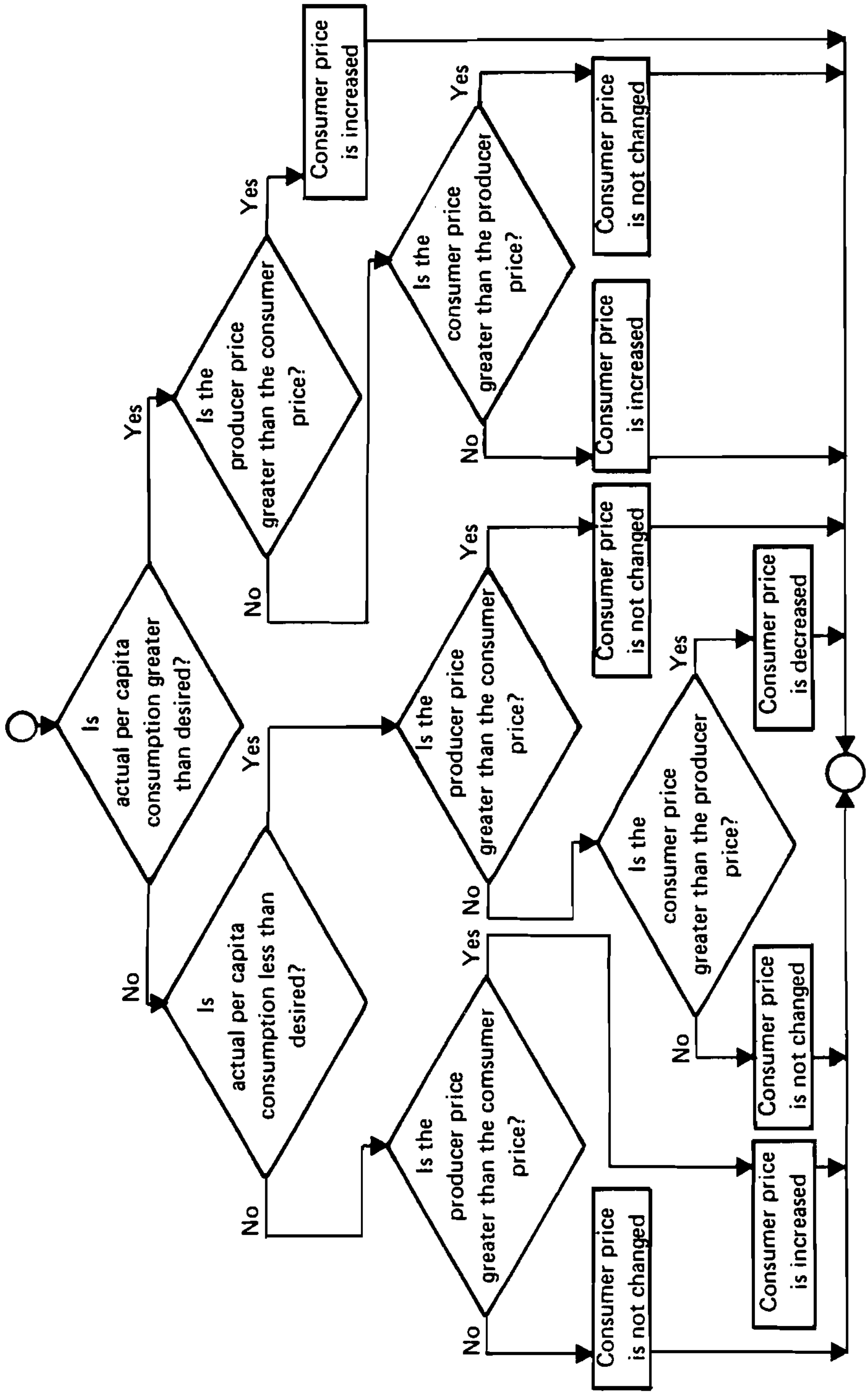


FIGURE 7 Revision of consumer prices.

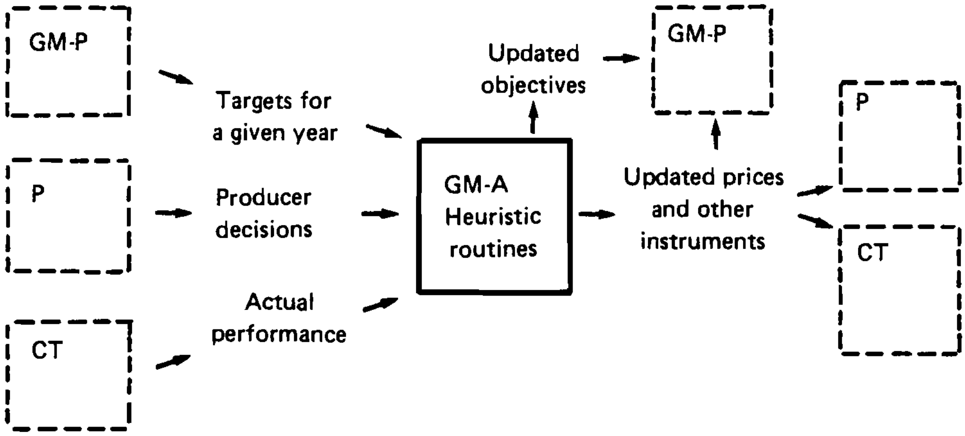


FIGURE 8 Role of government economic analysis block in HAM.

6 MATHEMATICAL DESCRIPTION OF HAM MODEL STRUCTURE

For each model block and module the detailed mathematical structures of the various equations are now described in the order of computation.

6.1 System of Symbols Used

The system of symbols used is as follows (the meanings of symbols used in HAM are listed in the Appendix).

Superscripts

h, s, p, n	Producer sector (household and private agriculture, socialist sector of agriculture, food processing, rest of the economy)
c, pr, w	Price categories (consumer, producer, world market)
*	Yields affected by weather
g	Government
po	Population
i, e	Import, export
in, l, wa, so	Type of tax
′	Lower limit
″	Upper limit

Subscripts

i	Agricultural commodity i
f	Processed food commodity f

n The nth commodity
l Land resource
m The additional activities
g General management and overhead activities
An underscore (_) denotes the symbol over which to sum.

In parentheses

(t) Time period
$(a, b, \dots)$ Argument of function

Symbols

$a, a^{(t)}$ etc. Lower case Roman letters refer to exogenous and policy variables
α, β, γ etc. Greek letters refer to model coefficients
SP, LPHN etc. Capital letters refer to model variables

6.2 Modeling of the Government's Economic Planning Activity (GM-P)

As Fig. 2 shows, the Government Economic Management submodel (GM) is devoted to the simulation of policy making and planning (GM-P), and to economic analysis and the revision of policy instruments (GM-A) by the government of the centrally planned socialist state. Ours is one of the first attempts to present a mathematical description of this very complex area. The final formulation of this submodel, especially those parts related to policy instruments, therefore required detailed analysis of the system.

In Hungary, as in all CMEA countries, the basic framework of economic development is determined by the central planning activity of the government. The first block of HAM therefore has to be devoted to the government's economic planning. As has been mentioned, the basic long-range government objectives are taken as exogenous parameters in HAM. Further government planning activities are represented by the Government Planning Block (GM-P) of HAM which includes four modules: the calculation of major economic goals of government (GM-P-1), the fixing of food consumption targets (GM-P-2), the planning of food production and foreign trade (GM-P-3) and the setting of government investment targets (GM-P-4).

6.3 Calculation of Major Economic Goals (GM-P-1)

In the centrally planned economies a certain rate of growth is considered as a minimum requirement for the economy. GM-P-1 is concerned with the determination of these requirements. In HAM the desired level of gross national product of food and agriculture, the desired growth of private consumption and the required positive balance of payments related to agriculture and food processing are fixed based on the exogenous long-range objectives.

First the desired net national product is fixed and in addition the planned accumulation fund available for food and agriculture is also calculated as follows:

$$PNNP^{(t)} = eNNP^{(t-1)}$$

$$DGNP^{(t)} = (1 + a)GNP^{(t-1)}$$

$$DGNPA^{(t)} = (1 + b)GNPA^{(t-1)}$$

$$DPBA^{(t)} = \sum_{t_1=t-3}^{t-1} PBA^{(t_1)}/3$$

$$PAF^{(t)} = (1 - f^{(t)})(PNNP^{(t)} + DESPN^{(t-1)} - PYO^{(t)})$$

$$PAFA^{(t)} = g^{(t)}PAF^{(t)}$$

$$PAFN^{(t)} = (1 - g^{(t)})PAF^{(t)}$$

$$PDGINA^{(t)} = hPAFA^{(t)}$$

$$PGINS^{(t)} = PAFA^{(t)} - PDGINA^{(t)}$$

As far as the desired positive balance of payments from food and agriculture is concerned, the balance is determined on international dollar and ruble as well as on domestic producer prices. The desired balance of payment in dollar markets is given by

$$KA^{(t)} = (1 + c^{(t)})KA^{(t-1)}$$

$$PYO^{(t)} = (1 + c^{(t)})YO^{(t-1)}$$

Finally, based on the desired annual growth rate of private consumption, the target value of total consumption at producer prices is calculated as follows:

$$PCTOT^{(t)} = (1 + i^{(t)})(CONP^{(t-1)} + GPE^{(t-1)} + CONS^{(t-1)})$$

6.4 Plan for Consumption (GM-P-2)

In the GM-P-2 module a detailed plan for per capita consumption of commodities is elaborated. In connection with this, starting from the desired growth of total consumption, (private and community* consumption) first of all we have to ensure the following.

1. The planned consumption fund must satisfy the minimum consumption growth requirements (adjustment of the $f^{(t)}$ parameter):

$$PCF^{(t)} = f^{(t)}(PNNP^{(t)} + DESPN^{(t-1)} - PYO^{(t)} - YS^{(t-1)})$$

*Consumption of population financed from government budget (e.g. in hospitals, schools etc.).

If the planned consumption fund is not sufficient, then

$$PCTOT^{(t)} > PCF^{(t)}$$

$f^{(t)}$ is modified as follows:

$$f^{(t)} = PCTOT^{(t)}/(PNNP^{(t)} + DESPN^{(t-1)} - PYO^{(t)} - YS^{(t-1)})$$

and

$$PCF^{(t)} = PCTOT^{(t)}$$

2. The endowments of the population (personal income and fund for community consumption) are in accordance with the planned consumption fund (adjustment of $o^{(t)}$ and $ep^{g(t)}$). The income of the population is planned as follows:

$$PTPE^{(t)} = [(1 + o^{(t-1)})(WES^{(t-1)} + WEP^{(t-1)} + WEN^{(t-1)}) + BS^{(t-1)} + BP^{(t-1)}$$

$$+ BN^{(t-1)}]\,(1 - t^{\text{in,po}}) + es^{g}GSP^{(t-1)} - ASP^{(t-1)} + (1 - t^{\text{in,h}})INH^{(t-1)}$$

The planned community consumption of commodity i in physical units:

$$PTCG_i^{(t)} = (1 + ep^{g(t-1)})PTCG_i^{(t-1)}$$

and the sum in value:

$$PGPE^{(t)} = \sum_i p_i^{\text{pr}(t)} PTCG_i^{(t)}$$

If the planned income of the population does not meet the planned value of the consumption fund, the undesired deviations are alleviated by adjusting the targets for increases in wages and community consumption. The adjustment of unit wages for a given period takes place as follows. If

$$PCF^{(t)} > (PTPE^{(t)}/pci^{(t)} + PGPE^{(t)})(1 + \epsilon_1)$$

then

$$o^{t} = \min\,(o^{(t-1)} + \beta_3\,;ok'')$$

$$ep^{g(t)} = \min\,(ep^{g(t)} + \beta_4\,;ek'')$$

If

$$PCF^{(t)} < (PTPE^{(t)}/pci^{(t)} + PGPE^{(t)})(1 - \epsilon_1)$$

then

$$o^t = \max(o^{(t-1)} - \beta_3\,; ok')$$

$$ep^{g(t)} = \max(ep^{g(t-1)} - \beta_4\,; ek')$$

otherwise

$$o^t = o^{(t-1)}$$

$$ep^{g(t)} = ep^{g(t-1)}$$

Obviously the values of $PTPE^{(t)}$, $PTCG_i^{(t)}$ and $PGPE^{(t)}$ have to be recalculated using the adjusted $o^{(t)}$ and $ep^{g(t)}$ coefficients and

$$PJOV^{(t)} = PTPE^{(t)}/pci^{(t)} + PGPE^{(t)}$$

As the total endowment of the population is determined, the consumers' demands for various commodities are planned. The same method is used for determining expected consumer demand in a given year as for generating the final demand. We assume that the income of the population available after deducting savings and other commitments is spent in buying various commodities. Obviously in this case the planned sum of consumers' incomes is used. The planned consumer demand for a specific commodity is influenced by the consumer prices and the level of income, and is described as follows:

$$PTC_i^{(t)} = \rho_i^{(t)} PTPE^{(t)}/p_i^{c(t)}$$

where $\rho_i^{(t)} > 0$ and $\Sigma \rho_i^{(t)} = 1$. The $\rho_i^{(t)}$ parameters are determined using C.E.V. Leser's nonlinear demand model.

We assume that planned consumer expenditure on commodity i can be described as

$$PTC_i^{(t)} p_i^{c(t)} = c_{1(i)}(p_i^{c(t)}/PTPE^{(t)})^{c_{2(i)}} PTPE^{(t)} \Big/ \sum_j c_{1(j)}(p_j^{c(t)}/PTPE^{(t)})^{c_{2(j)}}$$

where $c_{1(i)}$ and $c_{2(i)}$ are parameters related to commodity i, and therefore

$$PTC_i^{(t)} = c_{1(i)} P_i^{c(t)(c_{2(i)}-1)} PTPE^{(t)(1-c_{2(i)})} / \sum_j c_{1(j)} P_j^{c(t)(c_{2(j)})} PTPE^{(t)(-c_{2(j)})}$$

Based on time series of $TC_i^{(t)}$, $p_i^{c(t)}$ and $TPE^{(t)}$, the c_1 and c_2 parameters were estimated using the least squares method.

$$\rho_i^{(t)} = c_{1(i)}(p_i^{c(t)}/PTPE^{(t)})^{c_{2(i)}} \Big/ \sum_j c_{1(j)}(p_j^{c(t)}/PTPE^{(t)})^{c_{2(j)}}$$

and $\rho_i^{(t)}$ expresses the share of commodity i in planned consumer expenditure in period (t).

Finally in the GM-P-2 module the planned consumption fund and total consumption are compared and if

$$PCF^{(t)} < \sum_i p_i^{pr(t)} PTC_i^{(t)} + PGPE^{(t)}$$

the value of planned per capita consumption from the rest of the economy is decreased until

$$PCF^{(t)} = \sum_i p_i^{\mathrm{pr}(t)} PTC_i^{(t)} + PGPE^{(t)}$$

6.5 Government Plan on Food and Agriculture (GM-P-3)

The most important element of the GM-P block is the third module (GM-P-3), which is actually a linear programming model for fixing central (government) plan targets on food production, exports and imports. These are the basis for the analysis of the performance in a given year.

Commodity balances are given in the GM-P-3 module for each agricultural and processed food commodity considered in the model (listed in Table 2). The foreign trade (exports and imports) and the stock variables are restricted according to the desired level of self-sufficiency and the exogenously given world market constraints (e.g. bilateral agreements). For example the commodity balance for agricultural commodity i is given by

$$PP_i^{(t)} - \left(\sum_{\underline{i}} \alpha_{i\underline{i}}^{(t)} PP_{\underline{i}}^{(t)} + \sum_f \alpha_{fi}^{(t)} PP_f^{(t)} + \alpha_{\mathrm{n}i}^{(t)} PP_{\mathrm{n}}^{(t)} + \sum_k \alpha_{ki}^{(t)} RI_k^{(t)} + PE_i^{(t)} + PS_i^{(t)}\right)$$

$$+ PI_i^{(t)} + S_i^{(t-1)} = PTC_i^{(t)} + PTCG_i^{(t)} + PTCS_i^{(t)}$$

$$c_i^{\mathrm{e}(t)\prime} \leqslant PE_i^{(t)} \leqslant c_i^{\mathrm{e}(t)\prime\prime} \qquad d_i^{(t)\prime} \leqslant PS_i^{(t)} \leqslant d_i^{(t)\prime\prime} \qquad c_i^{\mathrm{i}(t)\prime} \leqslant PI_i^{(t)} \leqslant c_i^{\mathrm{i}(t)\prime\prime}$$

The planned production of the rest of the economy is calculated as:

$$PP_{\mathrm{n}}^{(t)} = aP_{\mathrm{n}}^{(t-1)}$$

In this optimization model only the major physical resources of food production are considered. In the case of resource k in agriculture the constraints are formulated as:

$$\sum_i \alpha_{ik}^{(t)} PP_i^{(t)} \leqslant SKAPT_k^{(t)}$$

the resources of the household and private sector are also considered:

$$\sum_i \alpha_{ik}^{(t)} PP_i^{(t)} \leqslant SKAPT_k^{(t)} + HKAPT_k^{(t)}$$

Production capacities in the household sector are determined based on actual production in the previous period:

$$HKAPT_k^{(t)} = HP_k^{(t-1)} / \gamma^{\mathrm{k}}$$

The land constraints are formulated according to land categories (plowland, plantations, meadows and pastures) as follows:

$$\sum_i \alpha_{i1}^{(t)} PP_i^{(t)} \leqslant LS_1^{(t)} + LS_2^{(t)} + LSH^{(t)} - HP_i^{(t-1)} / APH_i - HP_{i+1}^{(t-1)} / APH_{i+1}$$

where commodities i and $i + 1$ are the plantations in the household and private sector. The production resources in food processing are modeled according to the major types of processing in the same way as for resources in agriculture:

$$\sum_f \alpha_{fk}^{(t)} PP_f^{(t)} \leqslant KAPT_k^{(t)}$$

The major economic goals fixed by module GM-P-1 appear in the GM-P-3 module as follows.

The required gross national product from food and agriculture is given by

$$\sum_i p_i^{\mathrm{pr}(t)} PP_i^{(t)} + \sum_f p_f^{\mathrm{pr}(t)} PP_f^{(t)} \geqslant DGNPA^{(t)}$$

and the required positive balance of payments for food and agriculture by

$$\sum_i p^{\mathrm{w}(t-1)} \left(PE_i^{(t)} - PI_i^{(t)}\right) + \sum_f p_f^{\mathrm{w}(t-1)} \left(PE_f^{(t)} - PI_f^{(t)}\right) \geqslant DBPA^{(t)}$$

Individual lower and upper limits may also be placed on the production of individual commodities to avoid extreme solutions due to linear programming algorithms. The resource utilization coefficients ($\alpha_{ik}^{(t)}, \alpha_{fk}^{(t)}$) are generated from the production block of the previous period in module UD-3. The labor force available is determined based on exogenously given trend coefficients and on the actual labor used in food and agriculture in the previous period.

For module GM-P-3 alternative goal functions can be considered, such as the maximization of the positive balance of payments from food and agriculture, max $PBPA^{(t)}$. The efficiency of agriucltural foreign trade can also be maximized through the maximization of net foreign exchange returns on domestic production expenditures at domestic currency as follows:

$$\max \sum_i (dsp_i^{\mathrm{w}(t)} - OKT_i^{(t-1)})(PE_i^{(t)} - PI_i^{(t)})$$

We are aware of the fact that actual agricultural policy objectives are much more complex than the possibilities afforded by an objective function. Several alternative objectives can be considered by changing the objective function.

The Hungarian government operates mainly by indirect economic regulators. The production plan targets generated by module GM-P-3 do not therefore appear directly in the Production block. The government's objectives are transferred mainly through policy variables (prices, subsidies) and a set of assumptions of the production models expressing long-range government requirements towards producers (e.g. cow stock cannot be decreased, or the food processing capacities have to be utilized to the level of available raw materials). Of course, a model may be constructed in which government plan targets appear directly in the Production block.

6.6 Investment Decisions of the Government: Module GM-P-4

In Hungary two forms of investments in food and agriculture are differentiated. The development of irrigation systems, infrastructures and some large investments in food processing are financed directly by the government. (However, in agriculture most investment decisions are made at the enterprise level.) In the GM-P-4 module, the investment decisions of government are modeled by a heuristic algorithm. The following basic information is used in making these calculations:

- the production facilities in food and agriculture in which the government might invest;
- the planned amount of funds available for direct government investments;
- shadow prices of scarce production facilities are supplied by the GM-P-3 module.

The possible fields of investments are ranked based on shadow prices generated by GM-P-3 LP. The resource with the largest shadow price has priority in the distribution of available funds. For each production facility a so-called investment unit is defined based on economy of scale and previous practice. Firstly one unit of investment is selected for the production facilities, starting with those having the largest shadow prices. After planning one investment unit in the production facility with the lowest positive shadow price, the procedure starts again planning the second investment unit at resource with the highest priority, and so on until all the available funds are utilized.

The algorithm for planning the government's investments is outlined in Fig. 9.

6.7 Modeling Production: Block P

The second major block of HAM is devoted to the description of producers' decisions and production itself. The main role of this block is to generate supply in a given unit of time. In contrast to other FAP models, three production sectors of food and agriculture are distinguished in HAM: household and private agriculture, socialist agriculture and food processing.

6.8 Household and Private Agriculture: Module P-1

In the formation of the production decision model for the household and private sector, the following main assumptions are made:

- as well as the household plots of cooperative farm members, private types of agricultural production, e.g. private farms and hobby farms, are considered;
- most of the resources for household and private production are given as reminders of former private farming and the extension of production to a given level does not require investment;
- household farming is closely linked with the socialist sector of agriculture in that a given amount of work is required by cooperative farms, most of the basic production operations of household crop production are executed by the machinery of cooperative farms and the socialist agricultural sector supplies feed regularly for animal husbandry in the household and private sector;
- some of the food products from the household and private farms are directly consumed by the owners of these farms.

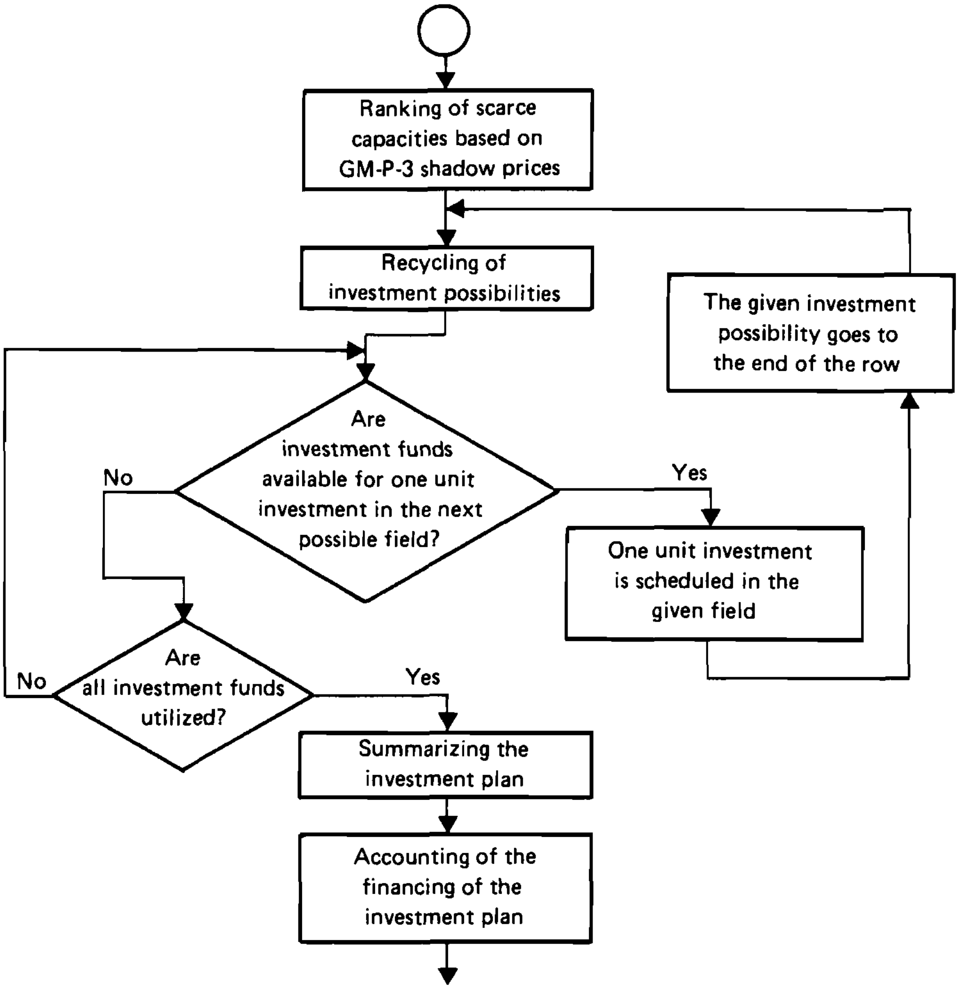


FIGURE 9 Procedure for planning government investments.

The most important part of the P-1 module describes the decisions on the product mix. The expected supplies of crops and animal products are determined by supply functions. To establish the most appropriate methodology for describing the behavior of household and private agriculture, several alternatives were investigated; these were linear programming, nonlinear optimization, trend interpolation and supply functions. The supply functions seemed to fit our objectives and the available data base most appropriately.

The supply of crop products is determined first. We assume that the supply of commodity i is a function of available land, producer prices and yields. The actual shares of various commodities in the total land available are determined using supply functions as follows:

$$hp_i^{(t)} = c_{3(i)}\,(1/p_i^{\mathrm{pr}(t)} APH_i LSH^{(t)})^{c_{4(i)}} \Big/ \sum_j c_{3(j)} (1/p_j^{\mathrm{pr}(t)} APH_j LSH^{(t)})^{c_{4(j)}}$$

The actual supply can be described as:

$$HP_i^{(t)} = h\rho_i^{(t)} LSH^{(t)} APH_i^{(t)}$$

The crop production is not constrained by labor availability. Household and private agriculture is based on work done mostly by cooperative farm members and workers in industry and elsewhere in addition to their main occupations and by women staying at home. The total amount of labor availability for this additional agricultural activity is modeled by a trend function reflecting a trend diminishing in time (see module UD-1). We assume always that the labor force over and above that needed for crop production is used for keeping animals in the household and the private sectors.

The total labor requirement of crop production is given by

$$TWHV^{(t)} = \sum_i HP_i^{(t)} WH_i^{(t)}$$

The labor force available for animal husbandry is given by

$$TWHA^{(t)} = TWH^{(t)} - TWHV^{(t)}$$

The supply of animal products is influenced by the availability of labor, by producer prices and by the productivity of labor in producing various commodities. In the same way as for crop production, the share of available labor for various commodities of animal husbandry is determined as follows:

$$h\rho_i^{(t)} = c_{3(i)}(WH_i^{(t)}/p_i^{\mathrm{pr}(t)}\, TWHA^{(t)})^{c_{4(i)}} \Big/ \sum_j c_{3(j)}(WH_i^{(t)}/p_j^{\mathrm{pr}(t)}\, TWHA^{(t)})^{c_{4(j)}}$$

and for the actual supply:

$$HP_i^{(t)} = h\rho_i^{(t)}\, TWHA^{(t)}/WH_i^{(t)}$$

The $c_{3(i)}$ and $c_{4(i)}$ parameters of supply functions can be estimated by using the least-squares method based on time series.

After projecting the production the intermediate input requirements of household and private agriculture are calculated as follows:

$$HD_j^{(t)} = \sum_i HP_i^{(t)} \mu_{ji}$$

These requirements are satisfied by the socialist sector of agriculture. In the case of inputs also produced by the household and private sector, the outgoing demand is obviously decreased by the internal supply:

$$(HBF_i^{(t)} - HP_i^{(t)}) > 0 \quad HD_i^{(t)} = HBF_i - HP_i^{(t)}$$

or if production exceeds internal needs:

$$(HBF_i^{(t)} - HP_i^{(t)}) \leqslant 0 \quad HD_i^{(t)} = 0$$

Agricultural production in the household and private sector for consumption within the sector is determined based on exogenously given trends:

$$TCS_i^{(t)} = (1 + hci)TCS_i^{(t-1)}$$

The total value of farm products used for self consumption is given by

$$CONS^{(t)} = \sum_i p_i^{\mathrm{pr}(t)} TCS_i^{(t)}$$

Finally the financial consequences of household and private agricultural production are calculated.

The gross production value is given by

$$HAP^{(t)} = \sum_i p_i^{\mathrm{pr}(t)} HP_i^{(t)}$$

Expenses related to the use of production facilities of socialist agriculture and expenses of material inputs are also calculated.

6.9 Production Decisions in Socialist Agriculture: Module P-2

Obviously the most important part of the production block is the production and investment decision model of the socialist agricultural sector. As far as the methodology is concerned, two options were considered, namely a nonlinear optimization model with production functions for each commodity and a linear programming model with different technologies for each commodity. Because of the lack of data required for the estimation of production functions and certain features of a farm's decision-making on inputs, a linear programming model is constructed to describe the behavior of state and cooperative farms. The possibilities of a more sophisticated mathematical representation of this sector were investigated, but finally the LP approach was kept.

The LP model is structured according to products. The production of most of the commodities is represented by two production variables which express two possible technologies of production, namely a "typical" present-day technology and a more capital-intensive and advanced so-called future technology. Table 5 gives an overview of the model structure. The irrigated production is not considered as a separate production variable. We assume that certain parts (more in the case of advanced technology) of the land used for a specific commodity are irrigated. The inputs and expenses related to irrigation are considered as part of the total inputs and expenses. The technological coefficients of production variables are updated annually from the exogenously given trend of biological development. The speed of the shift from the present "typical" technology to the "future" technology is restricted for each commodity. In the linear programming model, the additional (mainly construction) activities of state and cooperative farms and the general management and overhead activities are treated using separate variables similar to production variables. The LP describing producers' decisions on the structure of production is the central element of module P-2.

TABLE 5 Structure of linear programming model for socialist agriculture.

	Constraints/ variables	Plant production SPT_{ij}^{t}	Annimal husbandry SPT_{ij}^{t}	Other activities SPT_{l}^{t}	Relation	Right-hand side
1	Objective function	$p_{i}^{\mathrm{pr}(t)}\gamma_{ij}^{s(t)}$	$p_{i}^{\mathrm{pr}(t)}$	1	$\rightarrow$	max
2	Plowland	1			$\leqslant$	LS_{1}^{t}
3	Pastures, meadows	1			$\leqslant$	LS_{2}^{t}
4	Other resource constraints	$a_{kij}^{s(t)}$	$a_{kij}^{s(t)}$	$a_{kl}^{s(t)}$	$\leqslant$	$SKAPT_{k}^{t}$ SLF^{t}
5	Commodity balances	$\gamma_{ij}^{s(t)} - a_{iij}^{s(t)}$	$-a_{iij}^{s(t)}$	$-a_{il}^{s(t)}$	$\geqslant$	HD_{l}^{t}

In the linear programming model of the socialist agricultural sector, the resource constraints are formulated first. Various land categories can be considered as follows*:

$$\sum_i \sum_j a_{ij1}^{s(t)} SPT_{ij}^{(t)} \leqslant LS_1^{(t)}$$

Other physical resources (buildings, machinery) constraints are given by

$$\sum_i \sum_j a_{ijk}^{s(t)} SPT_{ij}^{(t)} \leqslant SKAPT_k^{(t)} - HD_k^{(t)}$$

The use of the labor force is expressed as follows:

$$\sum_i \sum_j b_{ij}^{s(t)} SPT_{ij}^{(t)} = SLF^{(t)}$$

The outputs of the socialist sector can be determined by commodity balances, assuming that there is no planned inflow of agricultural raw materials into the socialist sector:

$$\sum_j \gamma_{ij}^{s(t)} SPT_{ij}^{(t)} = SPN_i^{(t)}$$

Individual lower and upper bounds are given on the size of the production variables to avoid an extreme solution and to ensure realistic behavior of the model.

$$PTS_i'^{(t)} \leqslant SPN_i^{(t)} \leqslant PTS_i''^{(t)}$$

These lower and upper bounds are determined based on the analysis of past changes in the production structure of state and cooperative farms.

The introduction of "future" or advanced technologies is also limited. The full substitution of traditional by future technologies is allowed for only in the last third of the 15-year time period considered. Assuming that j represents a "typical" technology and $j + 1$ a so-called "future" technology, these restrictions are formulated as follows:

*In the description of the P-2 LP model, in subscripts i refers to commodity, j to technology and k to production capacity.

$$SPT_{ij}^{(t-1)} \geqslant SPT_{ij}^{(t)}$$

$$SPT_{ij+1}^{(t)} \geqslant z_i^{(t)''} (SPT_{ij}^{(t)} + SPT_{ij+1}^{(t)})$$

In the objective function of the model, the gross income (production value minus direct production expenses) of farming is maximized:

$$\max \sum_i \sum_j \mathrm{inc}_{ij}^{(t)} SPT_{ij}^{(t)}$$

The $\mathrm{inc}_{ij}^{(t)}$ coefficients are updated in each period before solving the LP model.

Besides the LP model for determining the structure of production, module P-2 consists of calculations for the following purposes:

- to determine total input needs of production;
- to generate the total disposable income of farming;
- to determine the average unit production costs of various commodities.

The input requirements, i.e. fertilizers, pesticides and other industrial inputs and services and industrially processed protein and other feeds are calculated as

$$IRA_k^{(t)} = \sum_i \sum_j a_{ijk}^{(t)} SPT_{ij}^{(t)}$$

Next the disposable income is calculated as follows.
Gross production value:

$$SAP^{(t)} = \sum_i p_i^{\mathrm{pr}(t)} SPN_i^{(t)}$$

Amortization:

$$DES^{(t)} = \sum_k RS_k^{(t)} drs_k$$

Direct production expenses except industrial inputs and services are calculated as follows.
Land tax:

$$LTS^{(t)} = \sum_i \sum_j t^{\mathrm{l}(t)} SPT_{ij}^{(t)}$$

Inputs of agricultural origin:

$$MESS^{(t)} = \sum_i \sum_j p_i^{\mathrm{pr}(t)} a_{ij} SPT_{ij}^{(t)}$$

Inputs of food processing origin:

$$MESP^{(t)} = \sum_i \sum_j p_i^{\mathrm{pr}(t)} b_{ij} SPT_{ij}^{(t)}$$

General management and overhead expenses:

$$SGMN^{(t)} = en\,SGMN^{(t-1)}$$

$$SGMA^{(t)} = ea\,SGMA^{(t-1)}$$

$$SGMM^{(t)} = em\,SGMM^{(t-1)}$$

$$SGM^{(t)} = SGMN^{(t)} + SGMA^{(t)} + SGMM^{(t)}$$

Expenses on industrial inputs and services:

$$MESI^{(t)} = \sum_k p_k^{\text{pr}(t)} IRA_k^{(t)} + SGMN^{(t)} + HMI^{(t)}$$

Labor expenses and taxes on wages:

$$ADMS^{(t)} = (1 + ed)ADMS^{(t-1)}$$

$$SLF^{(t)} = SLF^{(t)} + ADMS^{(t)} + HWES^{(t)}/w^{\text{s}(t)}$$

$$WES^{(t)} = SLF^{(t)}\,w^{\text{s}(t)}$$

$$LES^{(t)} = (1 + t^{\text{wa}(t)})\,WES^{(t)}$$

Total production expenses:

$$TES^{(t)} = MESS^{(t)} + MESP^{(t)} + MESI^{(t)} + LES^{(t)} + DES^{(t)} + LTS^{(t)}$$

Disposable net income of socialist agriculture:

$$INCS^{(t)} = SAP^{(t)} - TES^{(t)} + IKTO^{(t)}$$

Most of the commodities are represented by two technological variables in this module. In order to be able to compare production expenses with producer prices the average unit production costs of commodities are also calculated as follows (in the description of the procedure, i refers to commodity, k to production capacity and j to technology).

$$BARMI_i^{(t)} = \sum_k SPT_{ik}^{(t)}(MESS_{ik}^{(t)} + MESP_{ik}^{(t)} + MESI_{ik}^{(t)} + LTS_{ik}^{(t)} + LES_{ik}^{(t)})$$

$$OKT_i^{(t)} = (BARMI_i^{(t)}/SPN_i^{(t)}) + (p_i^{\text{pr}(t)}SGM^{(t)}/SAP^{(t)})$$

Special rules might be needed to calculate the unit costs of some of the products (e.g. beef, lamb, poultry meat) as follows:

$$XT_e^{(t)} = BARMI_e^{(t)} + (p_e^{\text{pr}(t)}SPN_e^{(t)} + p_{e+1}^{\text{pr}(t)}SPN_{e+1}^{(t)}/SAP^{(t)})SGM^{(t)}$$

$$OKT_e^{(t)} = XT_e^{(t)} / SPN_e^{(t)}$$

6.10 Calculation of Final Outputs of Agriculture: Module P-3

The agricultural commodities available are calculated from the producers' decision models (P-1, P-2) with consideration of the random effects of weather conditions on yields of annual and perennial crops. Our main assumptions in introducing weather uncertainties into HAM are as follows:

- no random effects are considered on the yields of nonmarketable feeds (e.g. green feeds, scraps), pastures and meadows;
- only the outputs are modified by random effects, therefore the inputs are unaffected;
- the methodology used for projecting the effects of weather on agriculture is similar to that applied in other national agricultural policy models at IIASA and will be specified later;
- for commodities that can be either directly consumed, exported or processed, after the calculation of agricultural output the quantity available for processing is also determined here.

The weather effects on yields and the final output of agriculture are calculated in the P-3 module.

The random effects of weather on the yields of commodity *i* are given by

$$\gamma_i^{h(t)*} = \gamma_i^{h(t)} \theta_i^{h(t)}$$

$$\gamma_{ij}^{s(t)*} = \gamma_{ij}^{s(t)} \theta_{ij}^{s(t)}$$

where $\gamma_i^{h(t)*}$ and $\gamma_{ij}^{s(t)*}$ are the actual yields in period (t) and $\theta_i^{h(t)}$ and $\theta_{ij}^{s(t)*}$ express the effects of weather on yield.

Based on $\gamma_i^{h(t)*}$ and $\gamma_{ij}^{s(t)*}$, the final outputs of agriculture ($SPN_i^{(t)}$, $BPA_i^{(t)}$ and $HP_1^{(t)}$) can be calculated.

6.11 Food Processing: Module P-4

In the fourth module of the Production block the production of food processing is scheduled. In the first version of HAM a linear programming model was used for this purpose. We finally decided to substitute the LP model with a simulation algorithm. Because the structure of food processing is almost completely determined by available resources and raw materials, little space being left for optimization, the use of a simulation procedure seemed to be more appropriate. The basic principles of these algorithms are as follows:

- production facilities are considered according to major branches of the Hungarian food processing industry and are given mostly according to processed commodities in our commodity list;
- alternative usages of production facilities are not considered.

The production costs, income and income utilization of food processing are also calculated in relation to a given production program of food processing.

6.12 The Rest of the Economy: Module P-5

The nonfood production part of the economy is modeled in an aggregated way. In HAM the so-called *n*th commodity represents the rest of the economy including industrial production and all types of services. The scale of the *n*th sector is determined by the available labor and assets as follows:

$$p_n^{(t)} = \alpha_6 (NLF^{(t)})^{\alpha_7} (RN^{(t)})^{\alpha_8}$$

The available labor force is calculated as the rest of the total working population:

$$LAF^{(t)} = SLF^{(t)} + PLF^{(t)}$$

$$NLF^{(t)} = wp^{(t)} - LAF^{(t)}$$

In connection with the scale of activities in the rest of the economy, the related production expenses are also calculated:

$$WEN^{(t)} = w^{\mathrm{n}(t)} NLF^{(t)}$$

$$LEN^{(t)} = (1 + t^{\mathrm{wa}}) WEN^{(t)}$$

$$DEN^{(t)} = drn\, RN^{(t)}$$

$$MEN^{(t)} = p_n^{\mathrm{pr}(t)} \alpha_{nn}^{\mathrm{n}(t)} p_n^{\mathrm{n}(t)}$$

6.13 Investment Decisions of Producing Enterprises: Module P-6

The investment programs of agricultural and food-processing firms are determined here. Similar principles are applied in the case of government investments, but the replacement of equipment which has deteriorated is also considered. The simulation algorithm of module P-6 includes the following procedures.

1. First the replacement of aged production facilities is carried out. Replacement is scheduled if the utilization of the given resource exceeds the desired level and if funds for replacements are available.

In agriculture: if $SKAPIG_k/SKAPT^{(t)}_k > ups$ and the value of the depreciated equipment is equal to $dds_k RS^{(t)}_k$, then

$$POT^{(t)}_k = dds_k RS^{(t)}_k$$

Investment is scheduled if $INS^{(t)} \geqslant POT^{(t)}_k$. Obviously, available funds are adjusted after scheduling each type of replacement:

$$INS^{(t)} = INS^{(t)} - POT^{(t)}_k$$

(The outline of the procedure can be seen in Fig. 9.)

In food processing: if $KAPIG^{(t)}_k/KAPT^{(t)}_k > upp$ and the value of the depreciated equipment is equal to $ddp_k > RF^{(t)}_k$, then

$$POT^{(t)}_k = ddp_k RF^{(t)}_k$$

Investment is scheduled if $INP^{(t)} \geqslant POT^{(t)}_{(k)}$. Available funds are updated in a similar way as for agriculture as follows:

$$INP^{(t)} = INP^{(t)} - POT^{(t)}_{(k)}$$

2. The new investments in agriculture are scheduled on the basis of shadow prices generated by the producers' decision LP model in module P-2. Therefore, only those resources fully utilized are considered as candidates for new investments. The resources with greater shadow prices have priority when the investment funds are distributed. In a similar way as for government investment, for each investment option the scale of the investment is fixed as a preliminary measure and at first only one unit is scheduled. The allocation of investment funds continues in this way, one additional investment unit being scheduled each time until all the available funds are utilized. (An overview of the calculations is given in Fig.9.)

3. The new investments in food processing are scheduled on the basis of the rate of resource utilization. New investments might be planned if

$$KAPIG^{(t)}_k/KAPT^{(t)}_k \geqslant uip$$

then:

$$SPRI^{(t)}_{(k)} = KAPIG^{(t)}_k/KAPT^{(t)}_k$$

The resource with the larger $SPRI^{(t)}_{(k)}$ coefficient has priority. In a similar way as for agricultural investments, the investments in food processing are planned by investment units starting from the resource with the highest priority, scheduling one unit each time until all the available funds are utilized.

As far as financial funds are concerned, the firm's investments are based on the enterprise's own resources and government subsidies. Because of fixed domestic producer prices, it is possible to calculate the enterprise's own investment funds before solving CT block.

The amount of government subsidies generated in the GM-P block is subject to further adjustment in the CT block as a means by which to reach balance of trade equilibrium. Investments planned according to target values for government subsidies should therefore also be further modified. To avoid this additional step, module P-6 has actually been solved as a part of block CT in HAM-2 when the final amounts of government subsidies are available and the final investment program can be calculated immediately.

6.14 Consumption and Trade Block: Block CT

The Consumption and Trade Block plays a very important role in the operation of the whole system. The private and government consumption as well as the country's reactions to changing world market conditions are modeled by three modules.

6.15 Committed Demand: Module CT-1

The first step in module CT-1 is, on the basis of former model elements, to calculate the so-called committed expenditures which cannot be further modified during the simulation of one specific year. A simple calculation is required to determine:

- the gross production value, income and income untilization of the producing sectors (socialist agriculture, food processing, rest of the economy) including the total intermediate demands of production;
- the earnings and committed expenditure, including household farming, of the population;
- the governments's income from the population and producing firms and the committed expenditure of the government.

The major elements of committed demands may be broken down as follows:

Income and income utilization of socialist agriculture

$$INCS^{(t)} = SAP^{(t)} - (LES^{(t)} + MES^{(t)} + DES^{(t)} + LTS^{(t)}) + IKTO^{(t)}$$

If $INCS^{(t)} < 0$ then

$$DEF^{(t)} = -INCS^{(t)}$$

$$INCS^{(t)} = 0$$

Taxes paid by socialist agriculture:

$$TXS^{(t)} = t^{\text{in},s(t)} INCS^{(t)} + t^{\text{wa}} WES^{(t)} + LTS^{(t)}$$

Bonus paid by socialist agriculture to employee:

$$BS^{(t)} = \nu^{s} INCS^{(t)}$$

Investment funds of socialist agriculture:

$$IFES^{(t)} = (1 - (t^{\text{in},s(t)} + v^{s}))INCS^{(t)} + (1 - dc^{s(t)})DES^{(t)} + IFES^{(t-1)}$$

Income and income utilization of food processing industry

$$INCP^{(t)} = PAP^{(t)} - (LEP^{(t)} + MEP^{(t)} + DEP^{(t)})$$

If $INCP^{(t)} < 0$ then

$$DEP^{(t)} = DEF^{(t)} - INCP^{(t)}$$

$$INCP^{(t)} = 0$$

Taxes paid by food processing firms:

$$TXP^{(t)} = t^{\text{in},p(t)} + t^{\text{wa}}WEP^{(t)}$$

Bonus paid by food processing firms to employee:

$$BP^{(t)} = v^{\text{p}}INCP^{(t)}$$

Investment fund of food processing firms:

$$IFEP^{(t)} = (1 - (t^{\text{in},p(t)} + v^{\text{p}}))INCP^{(t)} + (1 - dc^{\text{p}(t)})DEP^{(t)} + IFEP^{(t-1)}$$

Income and income utilization of the rest of the economy

$$INCN^{(t)} = p_n^{\text{pr}(t)}\, p_n^{\text{n}(t)} - (MEN^{(t)} + LEN^{(t)} + DEN^{(t)})$$

If $INCN^{(t)} < 0$ then

$$DEP^{(t)} = DEF^{(t)} - INCN^{(t)}$$

$$INCN^{(t)} = 0$$

Taxes paid by the rest of the economy:

$$TXN^{(t)} = t^{\text{in},n(t)}INCN^{(t)} + t^{\text{wa}}WEN^{(t)}$$

Bonus paid by the rest of the economy to employee:

$$BN^{(t)} = v^{\text{n}}INCN^{(t)}$$

Investment fund:

$$IFEAN^{(t)} = (1 - (t^{\text{in},n(t)} + v^{\text{n}}))INCN^{(t)} + (1 - dc^{\text{n}(t)})DEN^{(t)} + IFEAN^{(t-1)}$$

Income and income utilization of population

$$INCPO^{(t)} = WES^{(t)} + WEP^{(t)} + WEN^{(t)} + BS^{(t)} + BP^{(t)} + BN^{(t)}$$

$$TXPO^{(t)} = t^{\mathrm{in,po}} INCPO^{(t)} + t^{\mathrm{in,h}} INH^{(t)}$$

Endowment of private consumers available for buying goods:

$$TPE^{(t)} = INCPO^{(t)} - TXPO^{(t)} - ASP^{(t)} + (1 - t^{\mathrm{in,h}}) INH^{(t)} + GSP^{(t)}$$

$$CPE^{(t)} = (1/t_{\mathrm{p}}^{(t)}) TPE^{(t)}$$

Savings function of population:

$$ASP^{(t)} = aspi\, INCPO^{(t)}$$

Population social benefits (e.g. pension) from government:

$$GSP^{(t)} = es^{\mathrm{g}}\, GSP^{(t-1)}$$

Government's income from taxes and centralized amortization funds

$$GT^{(t)} = TXS^{(t)} + TXP^{(t)} + TXN^{(t)} + TXPO^{(t)} + TXH^{(t)}$$

$$GD^{(t)} = dc^{\mathrm{s}(t)} DES^{(t)} + dc^{\mathrm{p}(t)} DEP^{(t)} + dc^{\mathrm{n}(t)} DEN^{(t)}$$

Finally, the gross and net national product for a given year can be calculated as follows:

$$GNPA^{(t)} = SAP^{(t)} + PAP^{(t)} + HAP^{(t)}$$

$$GNP^{(t)} = GNPA^{(t)} + p_n^{\mathrm{pr}(t)} p_n^{(t)}$$

$$DESPN^{(t)} = DES^{(t)} + DEP^{(t)} + DEN^{(t)}$$

$$AGF^{(t)} = MES^{(t)} + MEP^{(t)} + MEN^{(t)} + MEH^{(t)} - IKTO^{(t)}$$

$$NNP^{(t)} = GNP^{(t)} - AGF^{(t)} - DESPN^{(t)}$$

Growth rate of net national product:

$$ef^{(t)} = NNP^{(t)} / NNP^{(t-1)}$$

6.16 Modeling of Consumers' Demands: Module CT-2

Module CT-2 is an important part of this model block and the complete model as well, describing private consumption. The role of module CT-2 is to determine the per capita consumer demands assuming that the endowment of consumers after deduction of savings is spent on various commodities.

The consumer demand for a specific commodity is influenced by the prices and the level of endowment. In HAM the demand for commodity i is described as follows:

$$CP_i^{(t)} = \rho_i^{(t)} CPE^{(t)}/p_i^{c(t)}$$

$$\rho_i^{(t)} > 0 \quad \text{and} \quad \sum_i \rho_i^{(t)} = 1$$

where $CP_i^{(t)}$ is the per capita demand for commodity i in period (t), $CPE^{(t)}$ is the per capita endowment of consumers in period (t) and $p_i^{c(t)}$ is the consumer price of commodity i in period (t). The $\rho_i^{(t)}$ parameters are determined in the model for each simulated year by using C.E.V. Leser's nonlinear demand model. The demand system used here is the same as those in module GM-P-2. Here, instead of plan targets on consumers' incomes, the final endowment of the population is considered.

6.17 Exchange Module: Module CT-3

Module CT-3 is a crucial part of the whole model, where the final level of private and government consumption as well as stocks satisfying balance of trade equilibrium conditions are determined. It is very important to underline that the reaction mechanism of domestic demands to new world market conditions (prices) is described here.

After some unsuccessful attempts with linear programming based on Michiel Kayzer's suggestion, a relatively simple method was developed to solve module CT-3.

In this module the so-called noncommitted demands, which can be the subjects of further adjustment, are determined. The noncommitted demand for a specific commodity consists of various elements; therefore, let q_{ih} express the hth type of demand for commodity i. To reach a solution first we define a target level of the hth demand for commodity i ($q_{ih}^{(t)}$) and introduce a vector λ which indicates the extent to which the targets are realized. Obviously the realization levels are constrained between two bounds:

$$\lambda^* \leqslant \lambda \leqslant \lambda^{**}$$

Let us assume that y is the vector of supply after the deduction of committed expenditures, $p_i^{w(t)}$ is the world market price of commodity i, and k is the preliminary fixed balance of foreign trade.

The solution of module CT-3 is equal to the determination of the values of vector λ which satisfy

$$p^w \mathbf{Q} \lambda = p^w y + k$$

with

$$\lambda^* \leqslant \lambda \leqslant \lambda^{**}$$

and where $\mathbf{Q}$ is a matrix of noncommitted demands.

During the solution procedure a strict preference ordering of various types of demands is followed. In the event of changes in the world market prices a new λ vector has to be calculated. If no solution can be obtained, the λ^* and λ^{**} vectors have to be adjusted so that a solution can be reached. The calculation of vector λ is easily programmed. It is worthwhile to consider unity as an initial value of λ_i. It is obvious that in the event that the target is realized, $\lambda_i = 1$, and always $\lambda_i^* < 1$ and $\lambda_i^{**} > 1$.

The target values of noncommitted demands are determined as follows.

- As far as stocks are considered, so-called optimal stocks are taken as target values. These optimal stocks are fixed exogenously.
- As the target value of direct government investments in food and agriculture the value of $PDGINA^{(t)}$ (planned direct government investments in food and agriculture), as determined in module GM-P-1, is used. The target value of $GINN^{(t)}$ is calculated based on the value of $PAFN^{(t)}$ (planned capital accumulation of the rest of the economy) determined in module GM-P-1 and $IFEAN^{(t)}$ (firm's investment fund in the rest of the economy).
- Targets on government subsidies to investments in agriculture and in food processing ($PGINSA^{(t)}$, $PGINSP^{(t)}$) are determined in the GM-P-4 module as a part of determining government's investment.
- The targets on consumption $PTC^{(t)}$ are fixed in the GM-P-2 module based on commodity-specific trends.
- As targets on private consumption, the values of $TC_i^{(t)}$ related to consumer price for the given year and endowments calculated in module CT-1 determined by the nonlinear demand system are used.

λ^* and λ^{**} express the extent of allowed deviation from target levels. For the various elements of **Q** different λ^* and λ^{**} values are given, expressing the government objectives and policies in demand adjustment. Vector λ is determined using the algorithm mentioned above and the final values of variables included in matrix **Q** can be calculated. On the basis of the elements of the **Q** matrix the export–import vector is calculated:

$$EI_i^{(t)} = \sum_j q^{ij(t)} - y_i^{(t)}$$

If $EI_i^{(t)} \leqslant 0$ then $I_i^{(t)} = -EI_i^{(t)}$ and $E_i^{(t)} = 0$

If $EI_i^{(t)} \geqslant 0$ then $E_i^{(t)} = EI_i^{(t)}$ and $I_i^{(t)} = 0$

If $EI_i^{(t)} = 0$ then $E_i^{(t)} = 0$ and $I_i^{(t)} = 0$

The final values of government investment subsidies $PGINSA^{(t)}$ and $PGINSP^{(t)}$ are also calculated. Based on the latter information the investment program of the given year is finalized. In fact, as has already been mentioned, module P-6 is solved only at this point in full and final knowledge of the investment funds available.

6.18 Financial Account of a Given Year: Module CT-4

As the state satisfying the balance of payments equilibrium condition has been reached in module CT-3, in module CT-4 the government budget and domestic financial consequences of the given product utilization structure are calculated.

Exports, imports and consumer prices are calculated as follows:

$$TREP^{(t)} = \sum_i (dsp_i^{(t)} - p_i^{\mathrm{pr}(t)}) E_i^{(t)}$$

$$TRIP^{(t)} = \sum_i (p_i^{\mathrm{pr}(t)} - dsp_i^{\mathrm{w}(t)}) I_i^{(t)}$$

$$TRCP^{(t)} = \sum_i (p_i^{\mathrm{c}(t)} - p_i^{\mathrm{pr}(t)}) TC_i^{(t)}$$

If $TREP^{(t)} < 0$ then $GES^{(t)} = -TREP^{(t)}$ and $TREP^{(t)} = 0$ and $GES^{(t)} = 0$

If $TRIP^{(t)} \leqslant 0$ then $GIS^{(t)} = -TRIP^{(t)}$ and $TREP^{(t)} = 0$

If $TRCP^{(t)} < 0$ then $GCS^{(t)} = -TRCP^{(t)}$ and $TRCP^{(t)} = 0$

The total tariff receipts of government:

$$GTRP^{(t)} = TREP^{(t)} + TRIP^{(t)} + TRCP^{(t)}$$

The total amount of price subsidies of government:

$$GP^{(t)} = GES^{(t)} + GIS^{(t)} + GCS^{(t)}$$

Financial consequences of changes in stocks:

$$SDS^{(t)} = \sum_i p_i^{\mathrm{pr}(t)} (S_i^{(t)} - S_i^{(t-1)})$$

$$SDP^{(t)} = \sum_f p_f^{\mathrm{pr}(t)} (S_f^{(t)} - S_f^{(t-1)})$$

$$SDN^{(t)} = p_n^{\mathrm{pr}(t)} (S_n^{(t)} - S_n^{(t-1)})$$

Total amount of investments in a given year:

$$TIN^{(t)} = SDS^{(t)} + SDP^{(t)} + SDN^{(t)} + TINS^{(t)} + TINP^{(t)} + PDGINA^{(t)} + PAFN^{(t)}$$

Income of government:

$$GI^{(t)} = GT^{(t)} + GD^{(t)} + GTRP^{(t)}$$

Expenditures of government:

$$GE^{(t)} = GPE^{(t)} + GSP^{(t)} + GP^{(t)} + GINA^{(t)} + GINN^{(t)} + DEF^{(t)}$$

Balance of government budget:

$$GISX^{(t)} = GI^{(t)} - GE^{(t)}$$

Balance of payments related to food and agriculture:

$$PBA^{(t)} = \sum_i p_i^{w(t)} EI_i^{(t)}$$

6.19 Analysis of Results and Revision of Policy Instruments: Block GM-A

After the final results are obtained for a given year based on an analysis of the performance of the whole system, some of the basic policy variables and instruments in the model are revised in block GM-A (Economic Analysis of Government). By this stage of the model, attempts have been made to describe one of the most complex elements of centrally planned food and agriculture systems. This is one of the first approaches ever developed for modeling the sphere of agricultural policy in a centrally planned economy. Based on interviews with high-level officials and on analysis of present-day practice, the basic policy structure and principles used in revising overall objectives and policy instruments have been outlined. These structures and principles are taken as given in the model and only their implementation is really modeled. Changes in structure or in principles can be dealt with only by modifying the structure of the model.

6.20 Revision of Policy Variables Influencing the Whole System: Module GM-A-1

First the overall performance of the system is analyzed in order to revise instruments controlling the growth of the whole economy as well as that of its main branches. We assume that the major government objectives to reach a desired economic growth rate are basically realized by changing the rate of investment of national income and the shares of the major sectors in total investments.

We assume that the desired path of growth (lower and upper bounds within which the actual growth is considered to be satisfactory) is given exogenously. The procedure described in module GM-A-1 starts with the calculation of the actual growth rates for the given period as follows.

Growth of food and agriculture:

$$bf_1^{(t)} = \{(\sum_i p_i^{\mathrm{pr}(t-1)} SPN_i^{(t)} + \sum_i p_i^{\mathrm{pr}(t-1)} FPN_i^{(t)} + \sum_i p_i^{\mathrm{pr}(t-1)} HP_i^{(t)})/GNPA^{(t-1)}\} - 1$$

Growth of the rest of the economy:

$$bf_2^{(t)} = (p_{\mathrm{n}}^{\mathrm{pr}(t-1)} p_{\mathrm{n}}^{(t)} / p_{\mathrm{n}}^{\mathrm{pr}(t-1)} p_{\mathrm{n}}^{(t-1)}) - 1$$

Share of food and agriculture in total output:

$$r_1^{(t-1)} = GNPA^{(t-1)}/GNP^{(t-1)}$$

$$r_2^{(t-1)} = 1 - r_1^{(t-1)}$$

Growth of the whole economy:

$$af^{(t)} = r_1^{(t-1)} bf_1^{(t)} + r_2^{(t-1)} bf_2^{(t)}$$

The revision of instruments influencing overall growth depends on the relation of actual to desired growth. We have to distinguish between situtation in which the overall growth is within the desired boundaries and those in which actual growth is less or greater than desired. If the overall growth remains within the previously fixed lower and upper bounds, the growth of the economy is considered satisfactory and instruments are not revised. Otherwise adjustment takes place, the actual development of food and agriculture and the rest of the economy being considered in addition to their relation. As a whole, the GM-A-1 module consists of six basic cases of adjustments (Fig. 10 gives an overview of these cases).

Case 1

In case 1 overall growth is higher than desired and the development of the rest of the economy is also faster than desired. In this case, our objective is to decrease the growth of the rest of the economy, maintaining or increasing the rate of development in food and agriculture.

If actual investments exceed plan targets, the income tax rates ($t^{\text{in},\text{n}(t)}$) and the centralized part of the depreciation ($dc^{\text{n}(t)}$) are increased. If development in agriculture is slower than desired the share of food and agriculture in total investments ($g^{(t)}$) is also increased.

If actual investments meet targets or remain below the target level, the share of consumption in national income ($f^{(t)}$) is increased. In the case of unsatisfactory growth of food and agriculture, investments in this sector ($g^{(t)}$) are also increased.

Case 2

In case 2 overall growth is higher than desired and similarly for food and agriculture. Meanwhile the rate of development in the rest of the economy is satisfactory or less than desired. As for case 1, the overall growth of the economy has to be decreased, maintaining or increasing the rate of growth in the rest of the economy.

If actual investments in food and agriculture exceed plan targets, related income tax rates ($t^{\text{in},\text{s}(t)}$ and $t^{\text{in},\text{p}(t)}$) and the rates of centralized depreciation ($dc^{\text{s}(t)}$ and $dc^{\text{p}(t)}$) are increased. In the case of unsatisfactory development of the rest of the economy, investment in food and agriculture ($g^{(t)}$) is decreased.

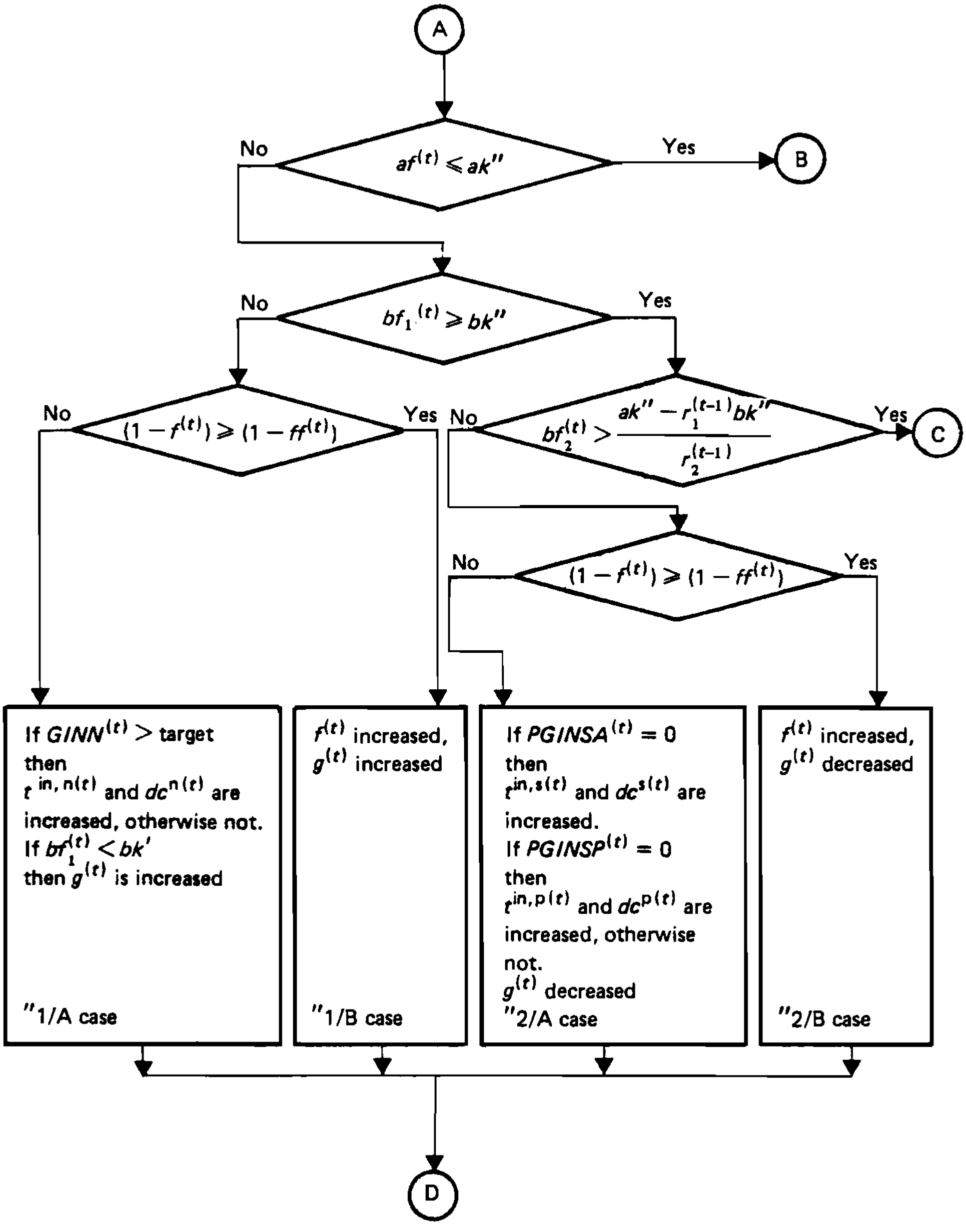
If actual investments meet targets or are below the target level, the share of consumption in national income ($f^{(t)}$) is increased. In the case of unsatisfactory growth of the rest of the economy, the share of food and agriculture in total investments ($g^{(t)}$) is decreased.

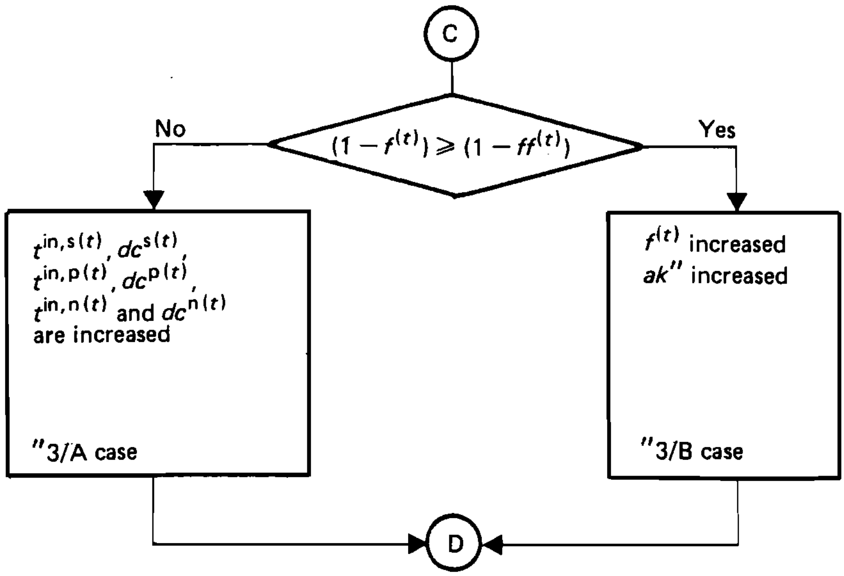
Case 3

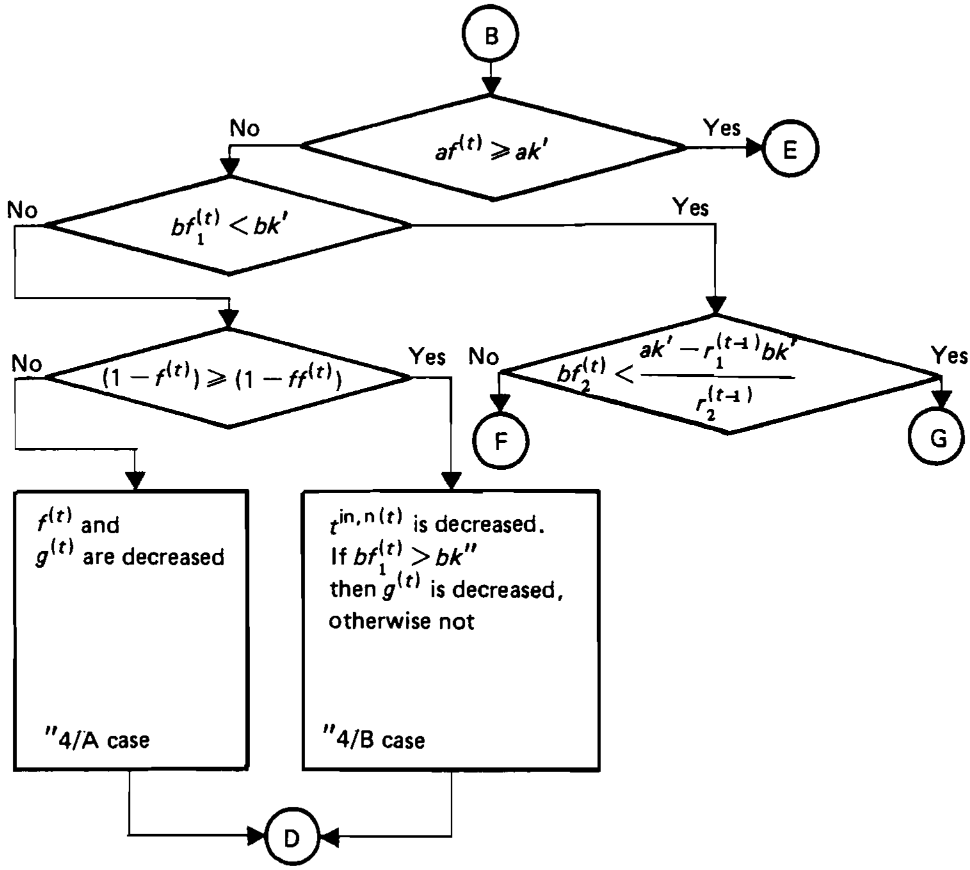
In case 3 overall growth is higher than desired and both food and agriculture and the rest of the economy develop faster than desired. Growth in both major sectors therefore has to be limited.

If actual investments exceed targets in both major sectors, income tax rates ($t^{in,s(t)}$, $t^{in,p(t)}$ $t^{in,n(t)}$) and centralized parts of depreciation ($dc^{s(t)}$, $dc^{p(t)}$, $dc^{n(t)}$) are increased.

If actual investments are below the target level the share of consumption ($f^{(t)}$) in national income is increased.




C
$(1-f^{(t)}) \geqslant (1-ff^{(t)})$
No
Yes
$t^{in,s(t)}$, $dc^{s(t)}$, $t^{in,p(t)}$, $dc^{p(t)}$, $t^{in,n(t)}$ and $dc^{n(t)}$ are increased
"3/A case
$f^{(t)}$ increased
ak'' increased
"3/B case
D


B
$af^{(t)} \geqslant ak'$
No
Yes
E
$bf_1^{(t)} < bk'$
No
Yes
$(1-f^{(t)}) \geqslant (1-ff^{(t)})$
No
Yes
$bf_2^{(t)} < \frac{ak' - r_1^{(t-1)} bk'}{r_2^{(t-1)}}$
No
Yes
F
G
$f^{(t)}$ and $g^{(t)}$ are decreased
"4/A case
$t^{in,n(t)}$ is decreased.
If $bf_1^{(t)} > bk''$ then $g^{(t)}$ is decreased, otherwise not
"4/B case
D

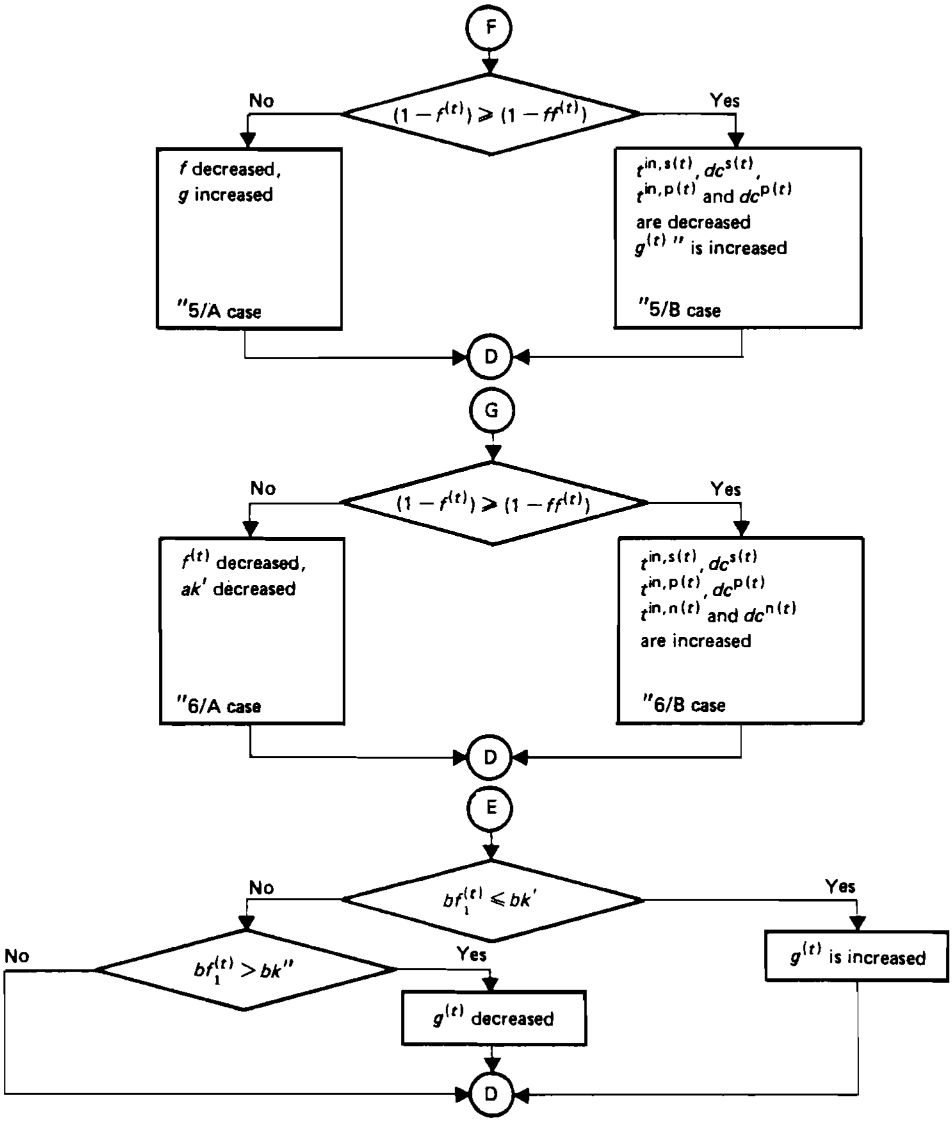


FIGURE 10 Revision of basic policy variables.

Case 4

In case 4 overall growth is below the desired level and the rest of the economy also develops slowly, but the rate of growth in food and agriculture is satisfactory or higher than desired. In this situation the growth of the rest of the economy is stimulated by increasing investments.

If actual investment exceeds targets, the share of investment in national income is increased ($f^{(t)}$ is decreased) and the share of the rest of the economy in total investment is also increased ($g^{(t)}$ is decreased).

If actual investment in the rest of the economy does not reach the target level the income tax rate ($t^{\text{in,n}(t)}$) and the centralized part of the depreciation ($dc^{\text{n}(t)}$) in the nth sector is decreased and the share of food and agriculture in total investments ($g^{(t)}$) might also be decreased.

Case 5

In case 5 the rate of overall growth is less than desired, similarly for the rates for food and agriculture, but the growth in the rest of the economy is satisfactory or faster. In this situation, obviously, investments in food and agriculture are encouraged at the expense of consumption and the rest of the economy.

If actual investments exceed the target levels overall, the consumption fund ($f^{(t)}$) is decreased and the share of food and agriculture in investments ($g^{(t)}$) is increased.

If actual investments are below the target level, income tax rates ($t^{\text{in,s}(t)}$, $t^{\text{in,p}(t)}$) and centralized depreciation ($dc^{\text{s}(t)}$, $dc^{\text{p}(t)}$) are decreased. The share of food and agriculture in investments ($g^{(t)}$) is increased.

Case 6

In case 6, in addition to slow overall growth, the rate of development both in the rest of the economy and in food and agriculture is below the desired level. In this situation, investment possibilities are enlarged for both sectors.

If actual investments are above the target levels, the total investment fund is increased at the expense of consumption ($f^{(t)}$ is decreased).

If actual investments do not reach the target levels, in addition to increasing the total investment fund, investment possibilities at the firm level (tax rates $t^{\text{in,n}(t)}$, $t^{\text{in,s}(t)}$ and $t^{\text{in,p}(t)}$ are increased and centralized depreciation $dc^{\text{n}(t)}$, $dc^{\text{s}(t)}$ and $dc^{\text{p}(t)}$ are decreased) might also be increased.

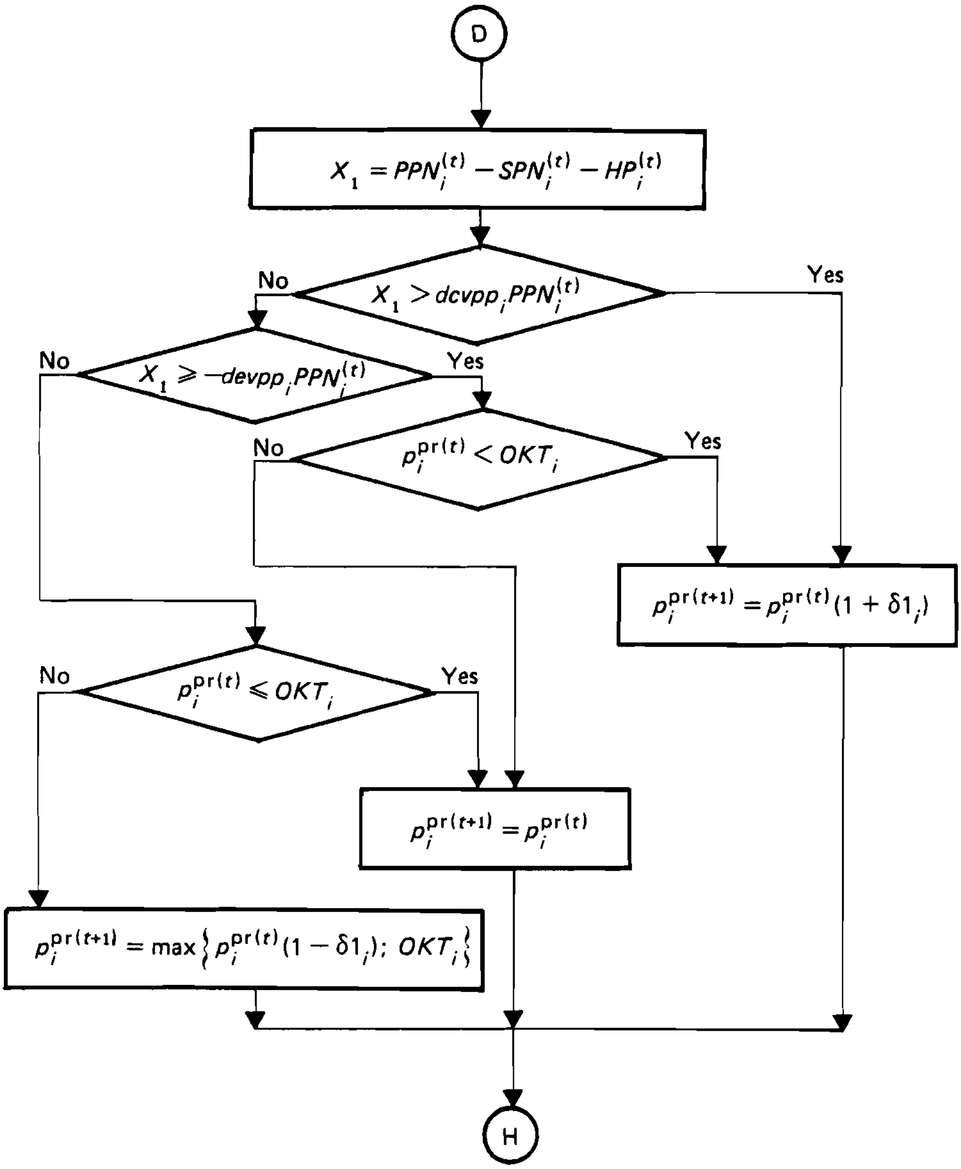
The diagram presented in Fig. 10 outlines the simulation procedure applied in module GM-A-1; the symbols used are explained in the Appendix.

6.21 Revision of Prices: Module GM-A-2 and GM-A-3

Domestic prices in Hungary are not directly related to international prices, but certain impacts of world market prices upon producer and consumer prices cannot be avoided. To develop module GM-A-2 and 3 the rather complex system of pricing employed in Hungary at present was studied. The pricing procedure included in HAM, we believe, explains the basic principles and logic of the Hungarian pricing system. However, we are aware of the fact that actual pricing is very largely commodity specific and influenced by the current economic situtation.

The revision of producer prices in HAM is based on the comparison of plan targets settled in module GM-P-3 with actual production results for the given year. Price revision depends on the length of time prices are to apply. The production expenses are also considered in the price modification. (The simplified process of producer price revision is shown in Fig. 11.) Production targets in the GM-P-3 module are actually determined on the basis of world market prices in the objective function, while actual production follows the domestic producer prices. World market prices have an impact on domestic producer prices by this indirect means.

In revising consumer prices (GM-A-3) the so-called desired structure of food consumption is used as a starting point. We assume that in changing consumer prices the government



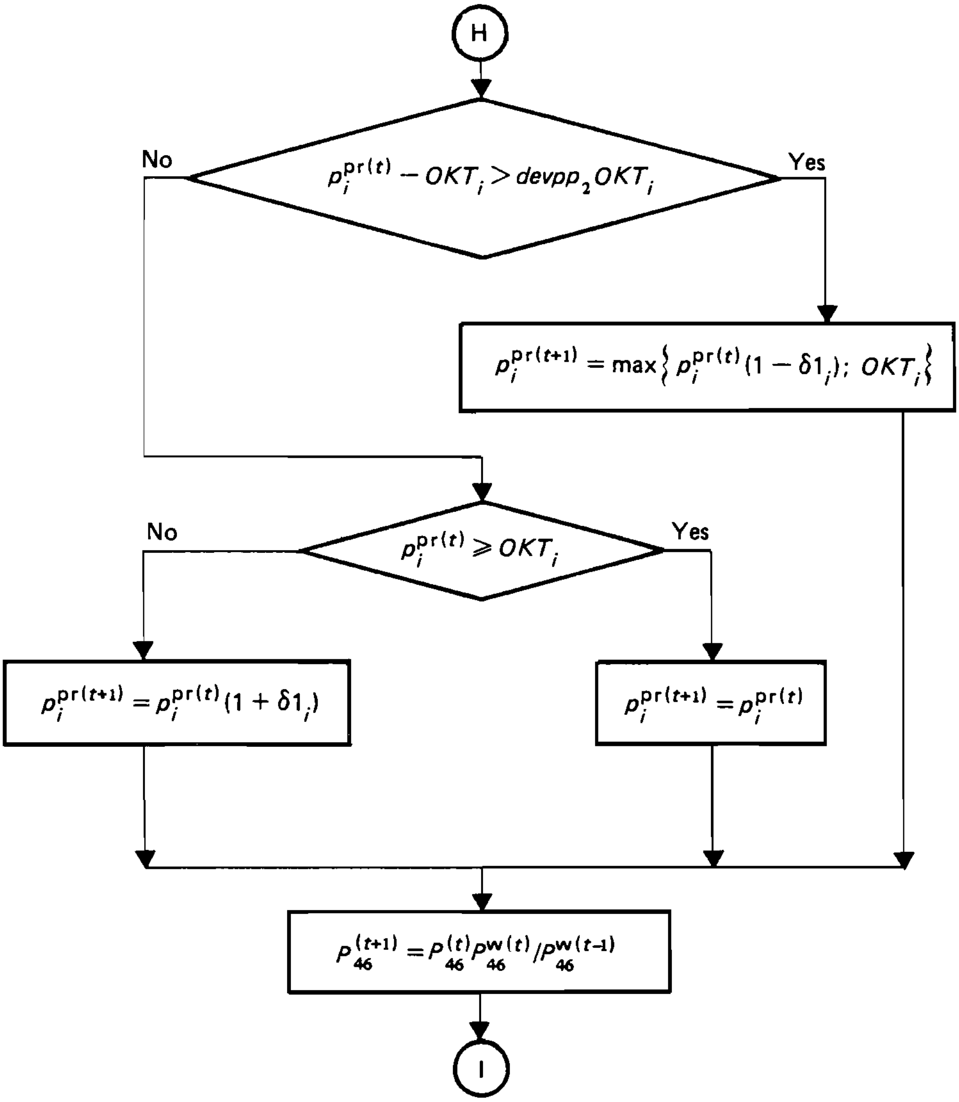
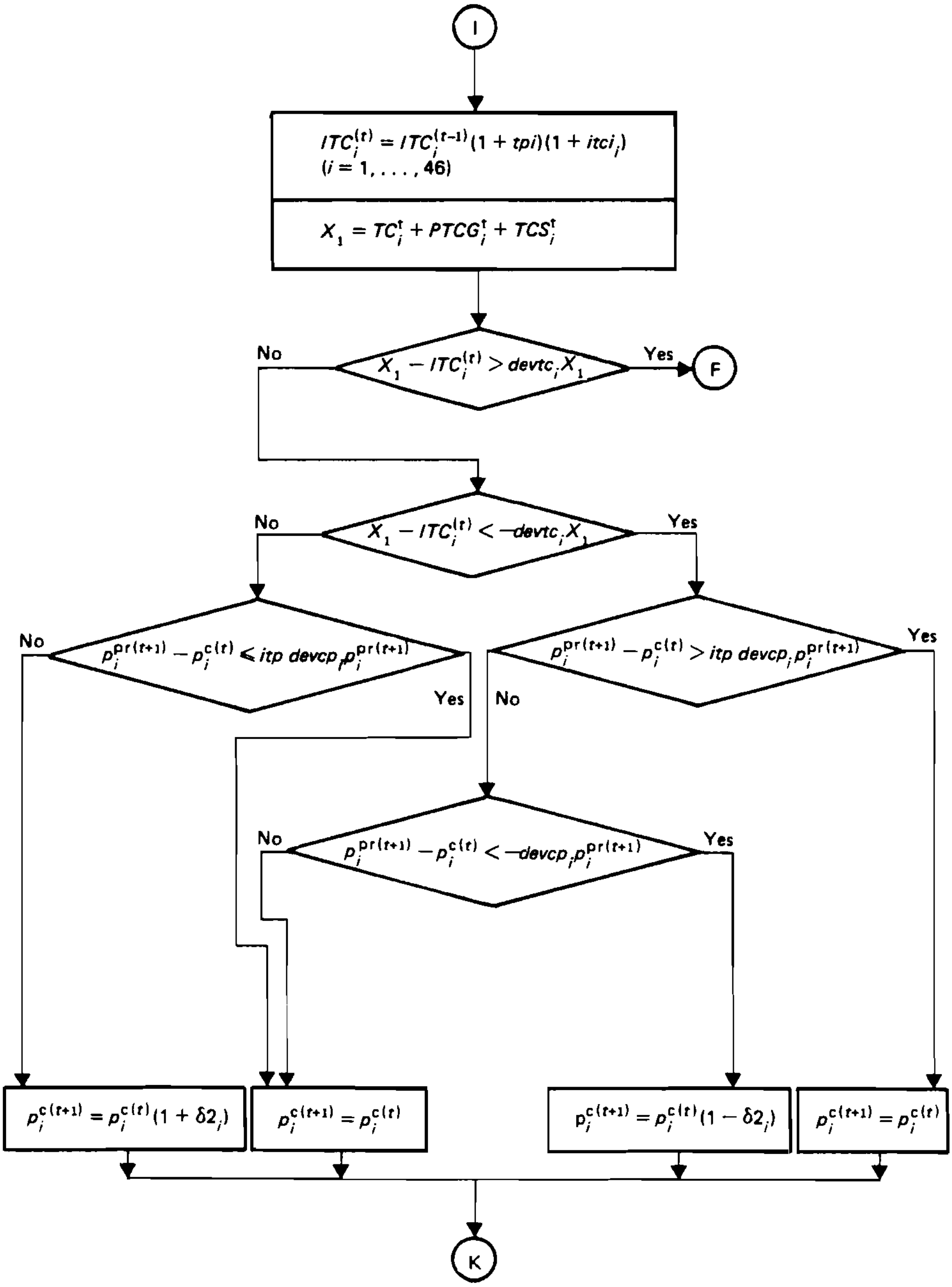


FIGURE 11 Process of revision of producers' prices.

aims at altering the actual structure to the desired structure. The desired structure of consumption is generated using exogenously given trends. Consumer prices might be modified if the actual consumption of a given commodity deviates substantially from the desired level of consumption. In modifying consumer prices the producer prices are also considered in order to keep the difference between the consumer and producer prices of a given commodity within a certain limit. The process of revising consumer prices is outlined in Fig. 12.


I
$ITC_i^{(t)} = ITC_i^{(t-1)}(1 + tpi)(1 + itci_i)$
$(i = 1, \ldots, 46)$
$X_1 = TC_i^t + PTCG_i^t + TCS_i^t$
No
$X_1 - ITC_i^{(t)} > devtc_i X_1$
Yes
F
No
$X_1 - ITC_i^{(t)} < -devtc_i X_1$
Yes
No
$p_i^{pr(t+1)} - p_i^{c(t)} \leqslant itp\ devcp_i p_i^{pr(t+1)}$
Yes
$p_i^{pr(t+1)} - p_i^{c(t)} > itp\ devcp_i p_i^{pr(t+1)}$
Yes
No
No
$p_i^{pr(t+1)} - p_i^{c(t)} < -devcp_i p_i^{pr(t+1)}$
Yes
$p_i^{c(t+1)} = p_i^{c(t)}(1 + \delta 2_i)$
$p_i^{c(t+1)} = p_i^{c(t)}$
$p_i^{c(t+1)} = p_i^{c(t)}(1 - \delta 2_i)$
$p_i^{c(t+1)} = p_i^{c(t)}$
K

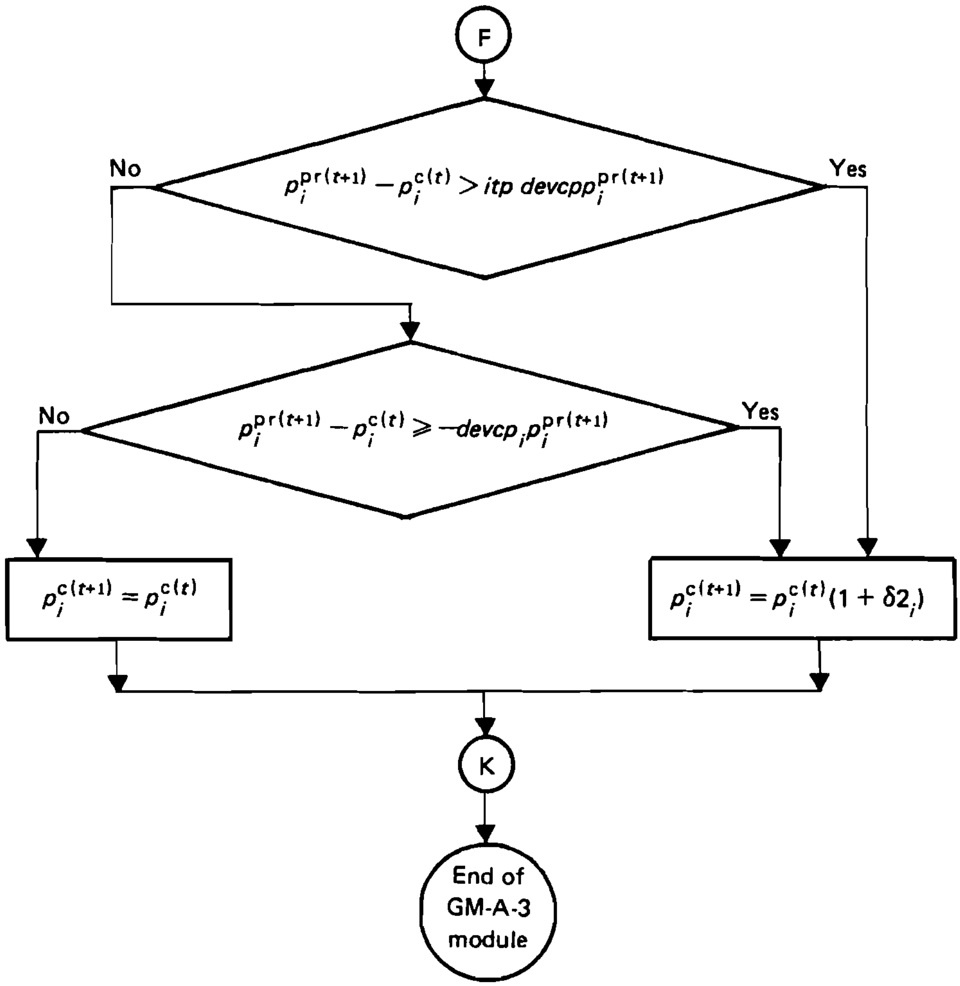


FIGURE 12 Revision of consumer prices.

6.22 Updating Parameters: Block UD

The last block of HAM-2 serves for the updating of parameters of the other model blocks – the last task during the modeling of a given time period. The UD block incorporates four modules:

- calculation of demographic changes (UD-1);
- updating of available land and physical resources (UD-2);
- calculation of new parameters for GM-P-3 module (UD-3);
- updatings of parameters for the Production block (UD-4).

6.22.1 Demographic changes: module UD-1

HAM does not include a demographic submodule. The available labor force and changes in population are calculated from a demographic prognosis elaborated by the Hungarian Central Statistical Bureau. The period of large-scale migration within the country ended in the late 1960s. Only a projected maximum decrease of the agricultural labor force is therefore considered. The available labor force in the household and private sector is forecast based on past trends.

The updating of the available labor force takes place based on the following three equations:

$$wp^{(t+1)} = wp^{(t)}(1 + wpi)$$

$$tp^{(t+1)} = tp^{(t)}(1 + tpi)$$

$$TWH^{(t+1)} = TWH^{(t)}(1 + wi)$$

6.22.2 Land and physical resources: module UD-2

The land available for agricultural purposes is modeled according to the socialist agriculture and household and private sectors. The regular decrease in the amount of plowland and meadows due to industrialization and urbanization is considered:

$$LS_1^{(t+1)} = LS_1^{(t)}(1 + lsi_1)$$

$$LS_2^{(t+1)} = LS_2^{(t)}(1 + lsi_2)$$

$$LSH^{(t+1)} = LSH^{(t)}(1 + lh)$$

The increase in physical resources is based on the investments of producing sectors as well as of the government. Obsolete production facilities are accounted for.

Fixed assets in the rest of the economy:

$$RN^{(t+1)} = RN^{(t)} - ddn\,RN^{(t)} + PAFN^{(t)}$$

Production facilities in agriculture:

$$RS_i^{(t+1)} = RS_i^{(t)}(1 - dds_i) + POT_i^{(t)} + INV_i^{(t-ati(i))}$$

$$SKAPT_i^{(t+1)} = SKAPT_i^{(t)}(1 - dds_i) + (POT_i^{(t)} + INV_i^{(t-ati(i))})/pks_i^t$$

Production facilities in food processing:

$$X_i^{(t)} = POT_{i+12}^{(t)} + INV_i^{(t-ati(i))}$$

$$RF_i^{(t+1)} = RF_i^{(t)}(1 - ddp_i) + X_i^{(t)}$$

$$KAPT_i^{(t+1)} = KAPT_i^{(t)}(1 - ddp_i) + X_i^{(t)}/pkp_i^t$$

6.22.3 Updating GM-P-3 model parameters: module UD-3

Food and agriculture is described in an aggregated way by the GM-P-3 model. Technical coefficients of variables representing the production of different food and agricultural commodities are calculated based on the Production block of the previous period as a weighted average of the various production options. The available resource and production facility capacities are taken from the UD-2 module.

6.22.4 Generation of the producers' decision model parameters: module UD-4

In agriculture the yields and output coefficients are calculated from functions estimated based on time series expressing biological development in plant production and animal husbandry. These functions are given according to technologies. The inputs are determined from the projected yields and outputs. The fertilizer use is calculated from fertilizer response functions.

The output coefficients of food processing are updated according to trends. The method of updating input coefficients is similar to those applied for adjusting agricultural parameters.

The parameters related to investment decisions are updated based on time trends.

PART TWO

Toward the Development of a Detailed National Policy Model – First Version of the Hungarian Agricultural Model (HAM-1)

1 OBJECTIVES IN DEVELOPING HAM-1

HAM is the first system simulation model to describe the Hungarian food and agriculture sector. The earlier modeling work provided much useful experience but in several cases HAM applies entirely new approaches and the development of HAM requires the analysis of several possible alternative methodological solutions. To avoid the difficulties of immediately working with a large-scale system we therefore decided first to develop a more aggregated, relatively simplified model version (HAM-1).

The main objective of HAM-1 was to gain methodological experience for the further refinement of our model structure and for the construction of the final model version through the following:

- testing the operation of the whole model system, investigating alternative methodological solutions for some of the model modules (e.g. using nonlinear optimization instead of linear programming);
- performing a sensitivity analysis of the crucial model parameters;
- studying the reaction of the system to changing external conditions (e.g. to changing world market prices);
- calculating the impacts of changes within the system (e.g. modifications of pricing mechanisms or decision-making rules) on the performance of the whole system.

HAM-1 is also very important from the point of view of computation of the final model version. Through the implementation of HAM-1 at IIASA and the computer of the Hungarian National Planning Bureau we intended to develop and test a computer program which could serve as a solid basis for the computation of the final model.

Our further objective with HAM-1 was to demonstrate that our model structure is suitable for investigations connected with the development of Hungarian food and agriculture in the following way.

- Based on the model, the realization of major policy goals and plan targets and their main alternatives can be investigated. For example, the key factors and bottlenecks of production, the considerations for faster growth, the expected labor outflow from agriculture and the feasibility of the goals may be analyzed.
- HAM is suitable for studying the adjustments and reactions of the Hungarian food and agriculture system to a changing international market. For example, the export and import structure, the desired level of specialization or self-sufficiency, and the reaction of the domestic to the world market may be investigated.
- Finally, HAM is designed to be useful for the further development of the Hungarian economic management system, since the model can analyze the efficiency of policy instruments, the impact of the new instruments, and areas of additional control requirements.

Finally, the investigation of data availability and the development of data collecting system for further work can also be mentioned as important objectives of the HAM-1 experiment.

2 DESCRIPTION OF HAM-I

HAM-1 describes the Hungarian food and agricultural sector in a rather aggregated way, but it has all the basic features of the HAM model structure described in Part One, namely:

- the model is dynamic and is descriptive in character;
- the food consumption sphere is incorporated;
- the nonfood production sectors of the economy are represented by assuming that they produce only one aggregated commodity;
- the economic, technical and biological aspects of food production are covered;
- both the production of agricultural raw materials and food processing are modeled;
- the whole agricultural production and food processing areas are represented;
- financial equilibrium is maintained.

Compared with our objectives as stated in the general description of the HAM structure, the aggregated and simplified features of HAM-1 mean the following:

- HAM-1 has a rather aggregated commodity coverage;
- different sectors of agricultural production (state farms, cooperative farms, household plots) are not considered – only the so-called socialist agricultural production (state and cooperative farms together) is modeled;
- random weather effects on agricultural production are not directly included;
- in some cases (e.g. the savings function) less sophisticated mathematical formulation is applied;
- the description of the government's policy instrument revision activities (e.g. pricing) can be considered as the first preliminary approach;
- no separate CMEA market is considered.

2.1 Commodity Coverage and Data Sources

The Hungarian food and agriculture system is described in HAM-1 on a relatively high level of aggregation. Hungarian food and agriculture is represented by five agricultural and four processed food commodities, the tenth commodity being related to the rest of the economy.

As is shown in Table 6, practically all the model commodities represent a relatively wide range of products. Altogether, almost the entire Hungarian food and agriculture and the national economy also are covered. The computed results of HAM-1 can therefore be compared with the actual indicators of Hungarian food and agriculture, and the national economy. Of the 10 commodities, six – wheat, pork, beef, sugar, processed meat and the *n*th commodity – are consumed by the population.

HAM-1 is based on official Hungarian statistics. The methodological character of the HAM-1 experiment allowed us to be less exacting and sophisticated in data preparation. Most of the model parameters were calculated using the data of the Hungarian National Statistical Bureau and the Ministry of Food and Agriculture. The consumers' demand system was estimated at IIASA based on time series.

TABLE 6 Commodity coverage of the first version of HAM.

	Product	Product content
1	Sugar beet	Sugar beet and other crop products to be processed
2	Corn	Coarse grains and other feed products
3	Wheat	Food grains and other directly consumed crop products
4	Swine	Swine (pigs)
5	Cattle	Cattle and other livestock products
6	Sugar	Sugar and other processed crop products
7	Pork	Pork meat
8	Processed meat	Processed meats
9	Beef	Beef and other meats
10	*n*th product	Product of the rest of the economy

2.2 Structure of HAM-1

HAM-1 is actually a system of models structured as it was planned in the general HAM outline. Figure 13 shows the structure of HAM-1. Some of the most important linkages and the operation of the model are shown in Figs. 14 to 16. Figure 14 shows how the overall government objectives on the growth of the economy are realized. The government production control mechanism and the government influence on comsumption are outlined in Figs. 15 and 16 respectively.*

2.3 Government Economic Planning Submodel

The GM-P submodel incorporates three modules. The calculation of major economic goals (GM-P-1) and government targets on consumption (GM-P-2) are executed as stated in the general model outline. A linear programming model is applied to fix government targets on food and agriculture (GM-P-3).

The GM-P-3 module contains 34 variables and 45 rows, including the objective function describing the maximization of the balance of payments in food and agriculture. The whole GM-P-3 model for the first year is shown in Appendix 2. The model coefficients are updated in each simulated year based on P-3 and P-5 modules, as described later.

2.4 Production Block

The Production block of HAM-1 consists of three major elements. The rest of the economy is modeled (module P-1) by a Cobb–Douglas-type production function as follows:

$$p_n^{(t)} = 290.3(LAN^{(t)})^{0.3}\ (RVN^{(t)})^{0.75}$$

*Figures 14–16 were designed by Professor Ferenc Rabar.

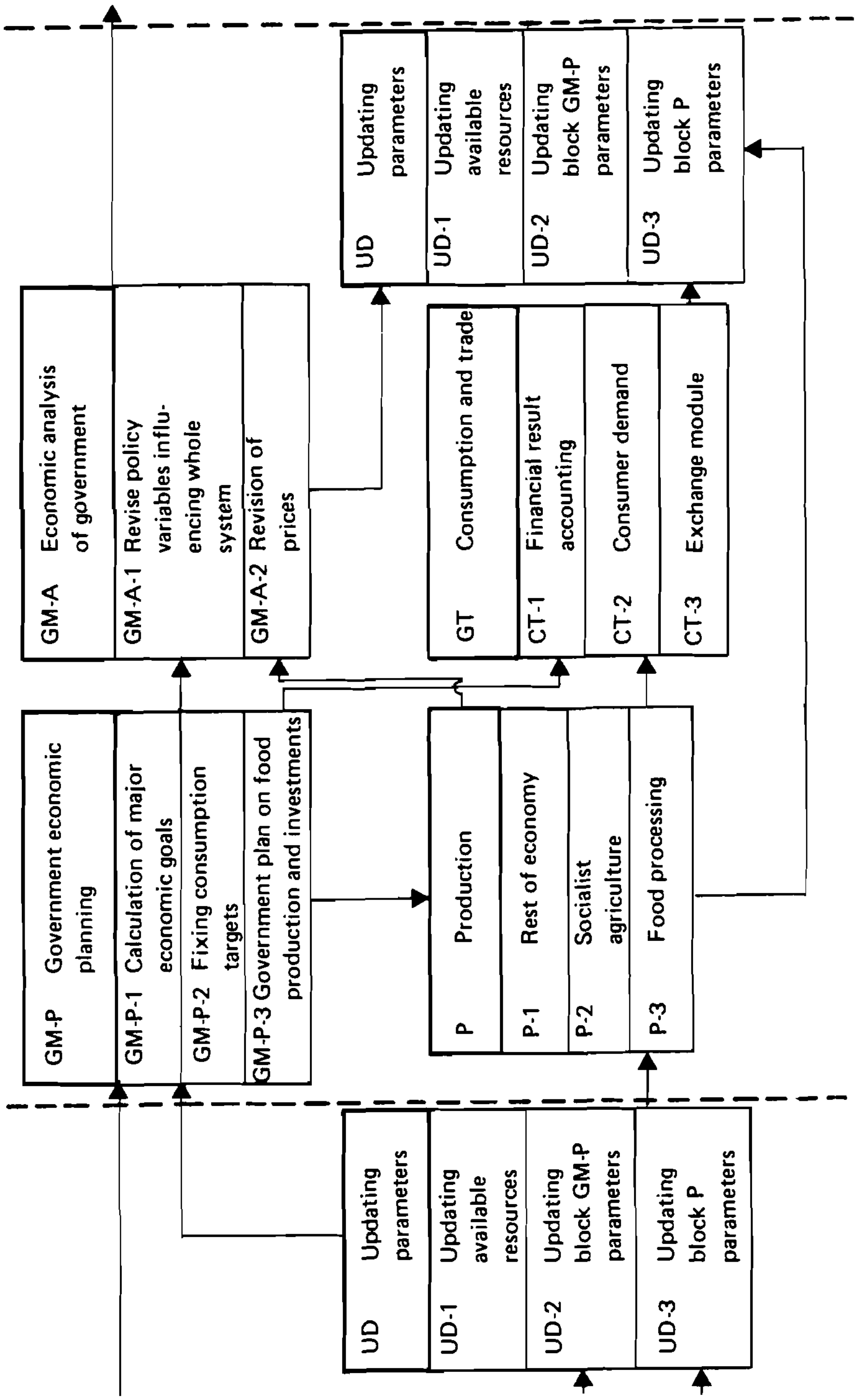


FIGURE 13 Schematic diagram of HAM-1.

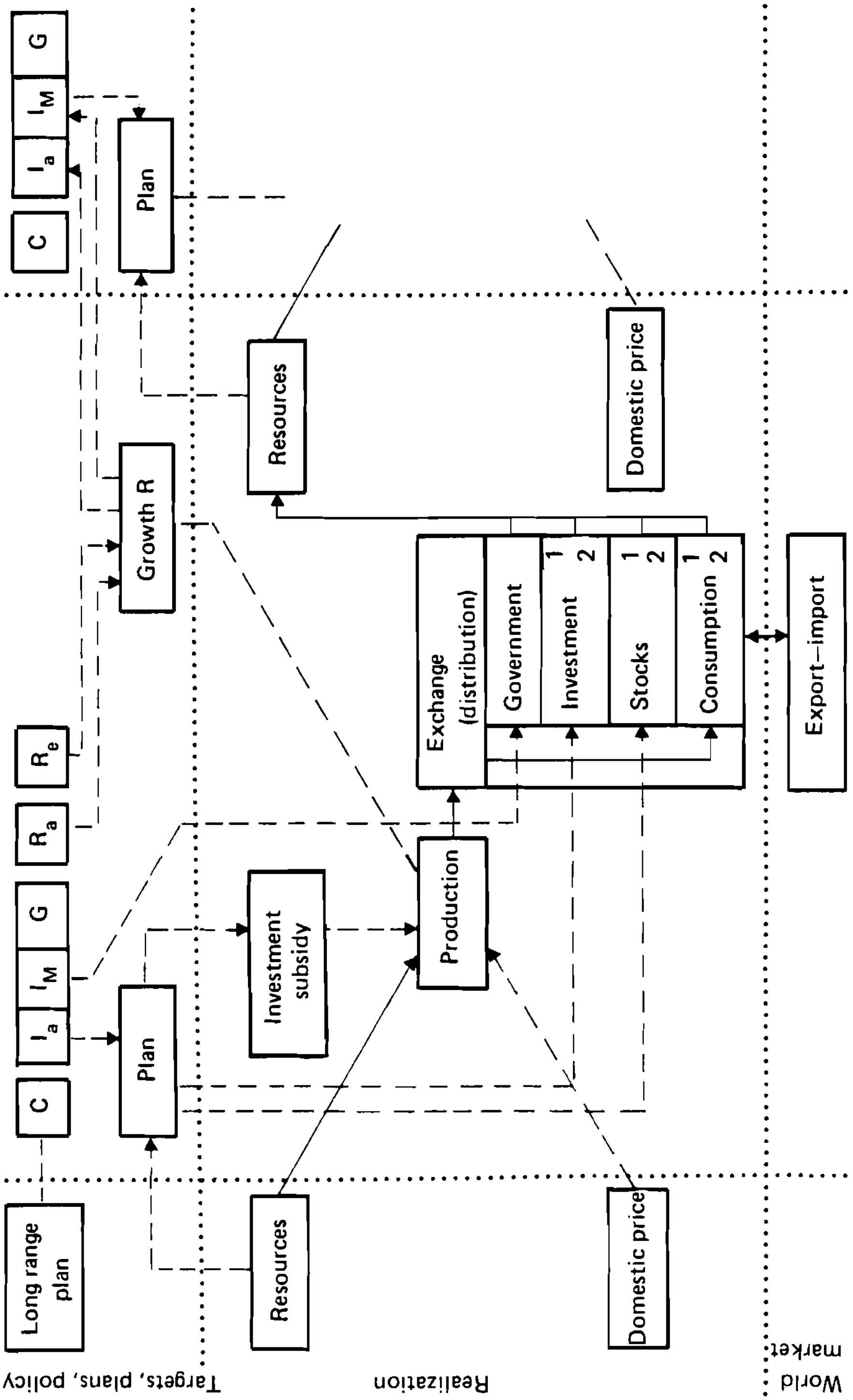


FIGURE 14 Control of the growth of the economy in HAM-1.

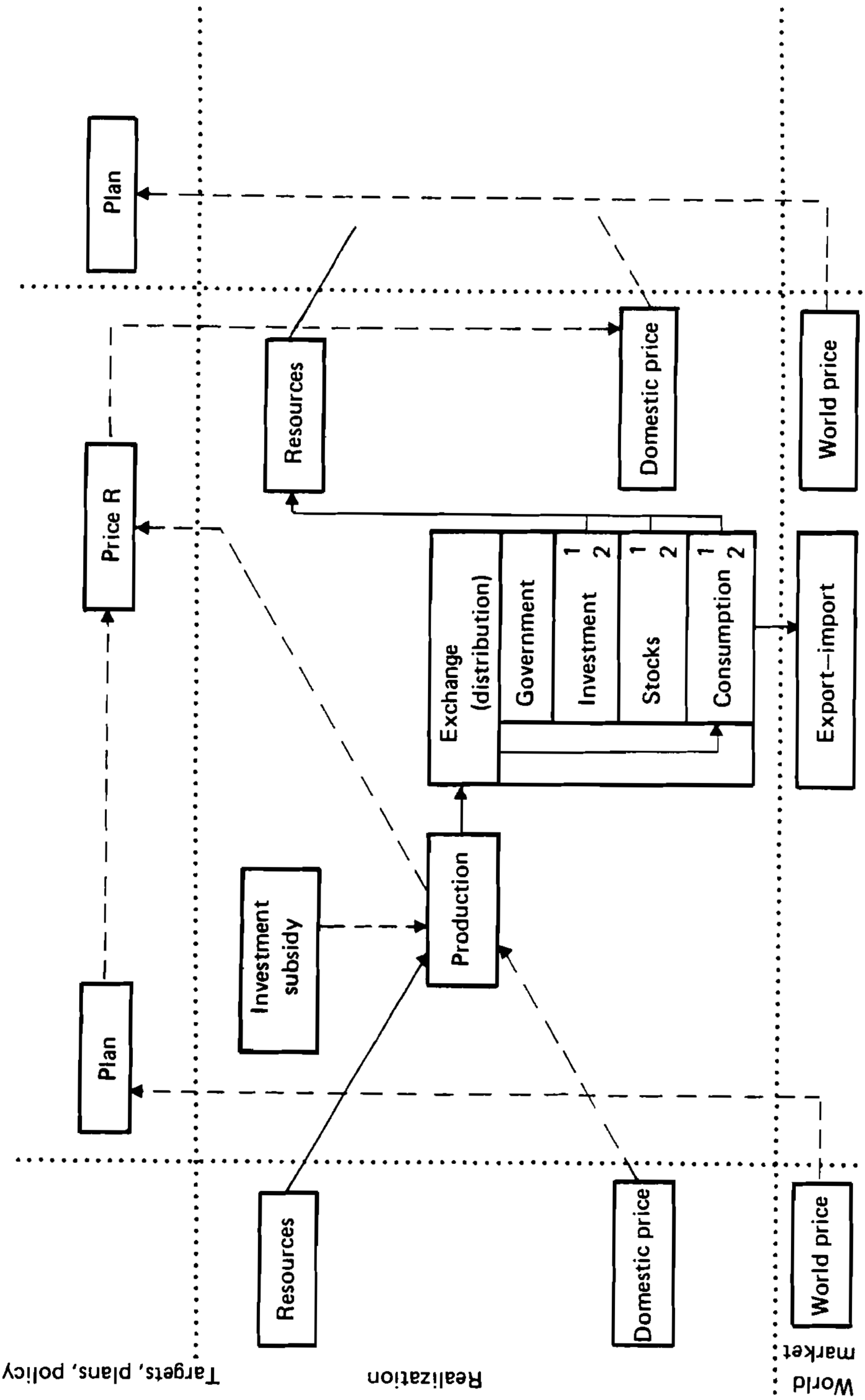


FIGURE 15 Government control of production in HAM-1.

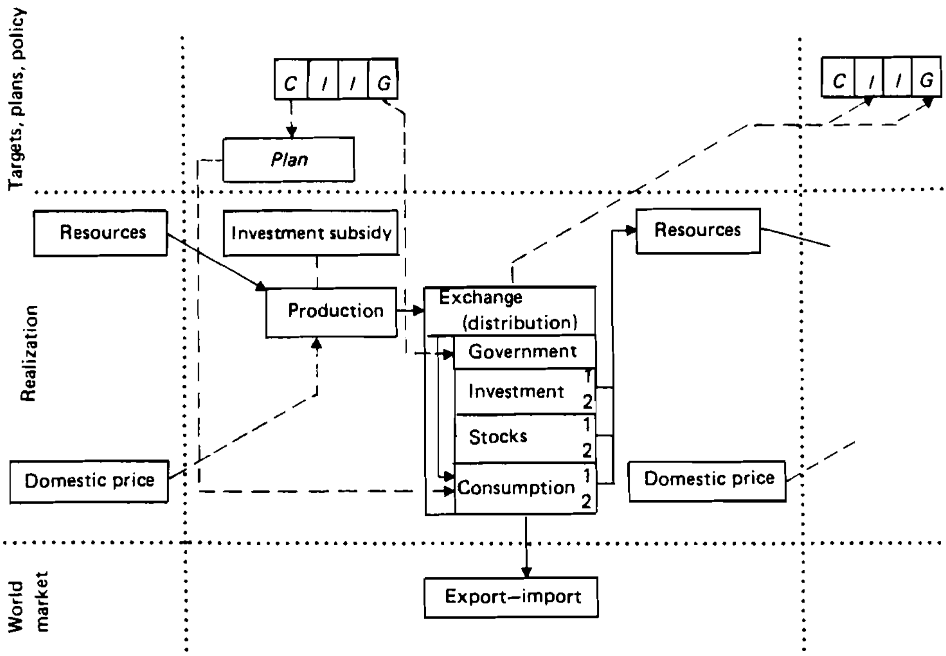


FIGURE 16 Government influence on consumption in HAM-1.

where $P_n^{(t)}$ is the production of the rest of the economy in period (t), $LAN^{(t)}$ is the labor force of the rest of the economy in period (t), and $RVN^{(t)}$ is the available assets of the rest of the economy in period (t).

Agricultural production and food processing are modeled by two separate linear programming models (module P-3 and P-5) determining first the agricultural production. As has been mentioned, random weather effects are not considered.

In the P-3 module the production of the five agricultural commodities is represented by two or three production technologies and a relatively wide range of input factors is considered. Module P-3 contains 22 columns and 31 rows including the objective function. Obviously, the P-3 model parameters are subject to annual updating according to the trends of biological and technical development as well as to domestic price changes.

Model P-5 is used to describe the production decisions of the food processing industry. The relatively small case linear programming model has 15 columns and 19 rows, and the results are to a large extent determined by available raw materials and processing capacities.

As can be seen from the description of the P-3 and P-5 modules, the investment decisions are included in production decision models in both cases and most of the investments have no time lag.

2.5 Consumption and Trade Block

The Consumption and Trade block of HAM-1 plays a very important role in the operation of the whole system. Some revision of the original structure of this model block was required during the work on it, but its basic content has not been changed from that of the general model outline.

The consumer demand is modeled according to our general model outline. The parameters of demand system used in HAM-1 are shown in Table 7.

TABLE 7 Parameters of the demand system used in HAM-1.

Commodity	*c*1	*c*2
1 Wheat	465.570	0.47800
2 Sugar	2.929	0.00535
3 Pork	240.550	0.57560
4 Processed meat	191.000	0.62140
5 Beef	19.463	0.13200
6 *n*th product	6.138	−0.24500

The demands related to noncommitted expenditures are formulated as in Table 8.

$S_i^{(t)}, S_f^{(t)}$ and $S_n^{(t)}$ are stocks in period (t);

$TC_i^{(t)}, TC_f^{(t)}$ and $TC_n^{(t)}$ are the total consumptions by the population of the various commodities;

$GPE^{(t)}$ is the government public expenditure in period (t);

$DGINA^{(t)}$ is the direct government investment in food and agriculture in period (t);

$GINN^{(t)}$ is the government investment in the rest of the economy;

$p_n^{\mathrm{pr}(t)}$ is the producer price of the nth commodity in period (t).

$\pi = 1/p_n^{\mathrm{pr}(t)}$

TABLE 8 Demands related to noncommitted expenditures.

i (agricultural commodities)	0	$S_i^{(t)}$	0	0	0	0	$TC_i^{(t)}$
f (processed food commodities)	0	$S_f^{(t)}$	0	0	0	0	$TC_f^{(t)}$
n (rest of the economy)	$S_n^{(t)}$	0	$\pi GPE^{(t)}$	$\pi DGINA^{(t)}$	$\pi GINN^{(t)}$	$TC_n^{(t)}$	0.

The structure of matrix **Q** expresses the preference ordering of adjustment as it is stated in the model outline, namely:

- adjustment of stocks of the nth commodity;
- stock adjustment of agricultural and processed food commodities;
- modification of government public expenditure;
- adjustment of direct government investment in food and agriculture;
- modification of government investments in the rest of the economy;
- adjustment of private consumption of the nth product;
- modification of private consumption of food and agricultural commodities.

This is the order of demand adjustment.

As has been mentioned in Part One, λ^* and λ^{**} express the extent of allowed deviation from target levels. For the various elements of Q different λ^* and λ^{**} are given, expressing the government objectives and policies in demand adjustment. Table 9 contains λ^* and λ^{**} vectors of HAM-1. Three sets of λ^* and λ^{**} are used in HAM-1, in which the extent of possible adjustment is increased continuously going from the first set to the third. Using the algorithm mentioned earlier, vector $\boldsymbol{\lambda}$ is determined and we obtain the final values of variables included in matrix Q as given in Table 9.

TABLE 9 Values of λ^* and λ^{**} used in HAM-1.

Parameter to which λ^* and λ^{**} are related	λ^*			λ^{**}		
	3	2	1	1	2	3
$S_n^{(t)}$	0	0.3	0.5	2	5	10
$S_i^{(t)}, S_f^{(t)}$	0.4	0.5	0.6	2	3	4
$GPE^{(t)}$	0.6	0.7	0.8	1.2	1.3	1.5
$DGINA^{(t)}$	0	0.3	0.5	1.2	1.5	2
$GINN^{(t)}$	0	0.3	0.5	3	4	5
$TC_n^{(t)}$	0.85	0.9	0.95	1.05	1.15	1.25
$TC_i^{(t)}, TC_f$	0.95	1.0	1.0	1	1.05	1.05

2.6 Economic Analysis of Government

The revision of the government policy instruments in HAM-1 is somewhat simpler than the procedures described in the general model outline. The actual values used in government policy instruments are determined in this module. These values have a great impact on the performance and operation of the whole system.

- Firstly the desired share of investment accumulation in net national product is updated for the next period. The procedure is based on the comparison of the actual growth of gross national product and those exogenous coefficients expressing the bounds of desired growth, as is shown in Fig. 17.
- The annual increase in unit wages is calculated based on the growth of net national product and the desired share of investment accumulation in net national product, as can be seen from Fig. 17.

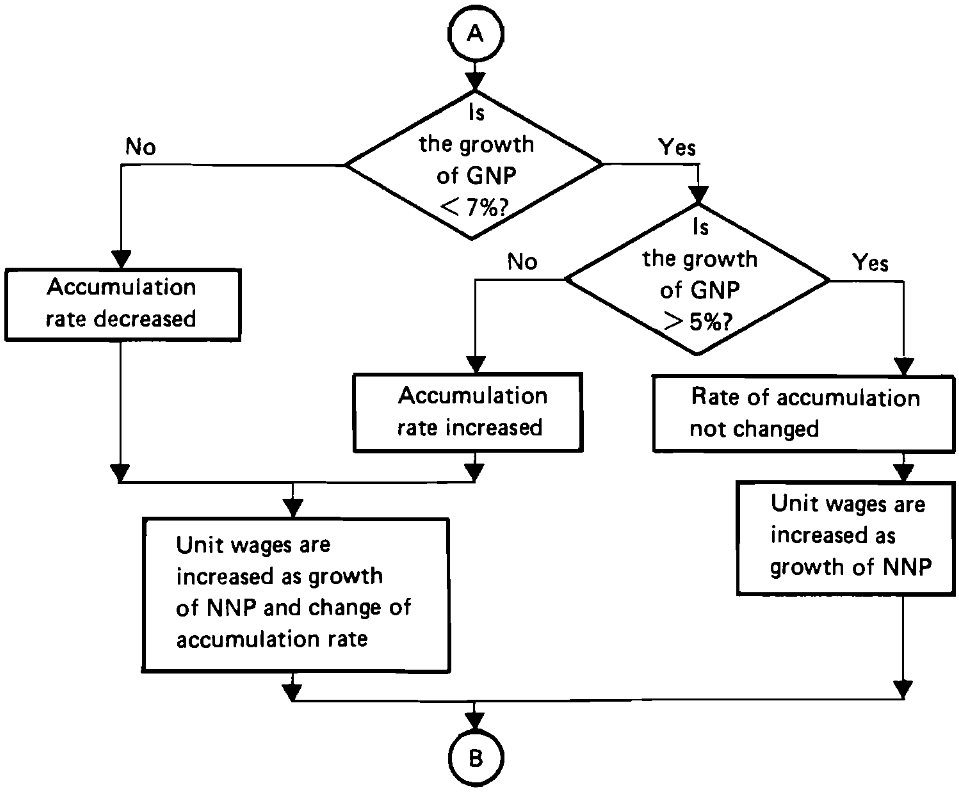


FIGURE 17 Revision of basic policy variables in HAM-1.

- The desired share of food and agriculture in total investment accumulation is revised based on the actual growth of gross production value of food and agriculture (see Fig. 18).
- The income tax rates are changed if the actual income rates are above or below certain given bounds, as shown in Fig. 18.
- Finally the producer and consumer prices are also revised. In HAM-1 this procedure is based on a comparison of target and actual figures of production, as shown in Fig. 19.

2.7 Updating Parameters

The last block of HAM-1 is devoted to the updating of parameters of other model blocks. The demographic changes are given exogenously based on a prognosis elaborated by the Hungarian Central Statistical Bureau. In HAM-1 only plowland is considered and some annual decrease of total land is projected as

$$LS^{(t)} = 0.9995\, LS^{(t-1)}$$

$LS^{(t)}$ is the total available plowland in period (t).

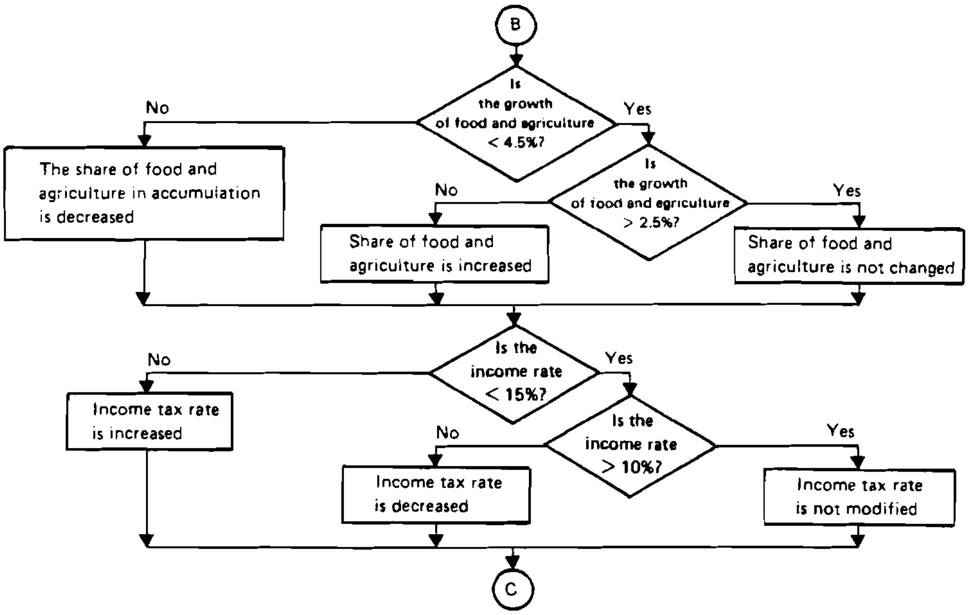


FIGURE 18 Revision of the desired share of food and agriculture in total investment and the income tax rate in HAM-1.

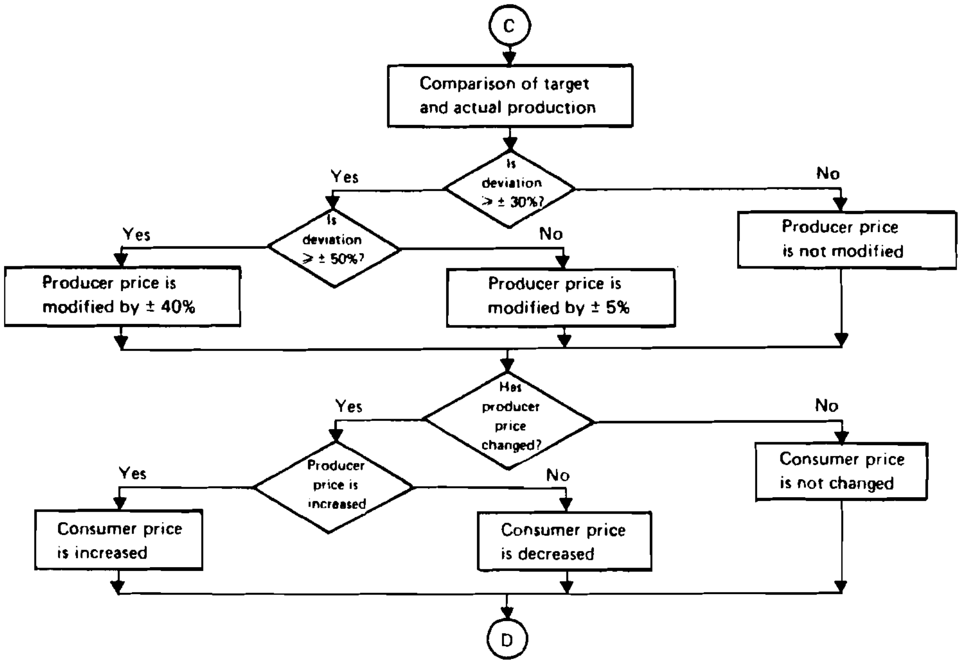


FIGURE 19 Revision of domestic prices in HAM-1.

TABLE 10 Initial values and updating of physical resources[a].

Resource	Unit	Initial value ($RS_i^{(0)}$, $RP_i^{(0)}$)	Updating
Tractors	1000s	440	$RS_1^{(t)} = 0.86RS_1^{(t-1)} + RIS_1^{(t-1)}$
Additional equipment	Millions of Hungarian forints	30 000	$RS_2^{(t)} = 0.87RS_2^{(t-1)} + RIS_2^{(t-1)}$
Pig barns	1000 head	9000	$RS_3^{(t)} = 0.95RS_3^{(t-1)} + RIS_3^{(t-1)}$
Cattle barns	1000 head	3000	$RS_4^{(t)} = 0.97RS_4^{(t-1)} + RIS_4^{(t-1)}$
Other fixed assets	Millions of Hungarian forints	50 000	$RS_5^{(t)} = 0.95RS_5^{(t-1)} + RIS_5^{(t-1)}$
Sugar processing	1000 tonnes	3600	$RP_1^{(t)} = 0.95RP_1^{(t-1)} + RIP_1^{(t-1)}$
Slaughtering capacity	1000 tonnes	2000	$RP_2^{(t)} = 0.95RP_2^{(t-1)} + RIP_2^{(t-1)}$
Meat processing plants	1000 tonnes	300	$RP_3^{(t)} = 0.95RP_3^{(t-1)} + RIP_3^{(t-1)}$

[a] $RIS_i^{(t)}$ and $RIP_i^{(t)}$ are increases in physical resources due to new investments in period (t).

TABLE 11 GM-P-3 module coefficients determined based on P-3 module in HAM-1.

	Sugar beet production	Corn production	Wheat production	Pig production	Cattle production
	PP_1	PP_2	PP_3	PP_4	PP_5
	2	3	4	5	6
4 Tractor	e_{42}	e_{43}	e_{44}		
5 Other equipment	e_{52}	e_{53}	e_{54}		
6 Pig barns				e_{65}	
7 Cattle barns					e_{76}
8 Other fixed assets	e_{82}	e_{83}	e_{84}		
12 Labor	$e_{12.2}$	$e_{12.3}$	$e_{12.4}$	$e_{12.5}$	$e_{12.6}$
14 Land	$e_{14.2}$	$e_{14.3}$	$e_{14.4}$		
30 Corn		1		$-E_4$	$-E_5$

In agricultural production the fixed assets are represented by five types. In food processing three basic production resources are considered. Table 10 shows the method of updating and the initial stock of these resources.

The coefficients of module GM-P-3 are calculated based on P-3 and P-5 modules. If only one production technology is considered in food processing, the parameters of P-5 are simply used in the GM-P-3 module. In the case of agricultural production, the GP-P-3 linear programming model parameters are determined based on the previous year's P-3 module. Table 11 contains a section of the GM-P-3 model and in Table 12 the altered part of the previous year's P-3 module is shown. The parameters for the GM-P-3 module are calculated as:

$$e_{42} = (\alpha_{20.2} SP_{11}^{(t-1)} + \alpha_{20.3} SP_{12}^{(t-1)} + \alpha_{20.4} SP_{13}^{(t-1)})/$$
$$(\gamma_{11} SP_{11}^{(t-1)} + \gamma_{12} SP_{12}^{(t-1)} + \gamma_{13} SP_{13}^{(t-1)})$$

$$e_{43} = (\alpha_{20.5} SP_{21}^{(t-1)} + \alpha_{20.6} SP_{22}^{(t-1)})/(\gamma_{21} SP_{21}^{(t-1)} + \gamma_{22} SP_{22}^{(t-1)})$$

$$e_{44} = (\alpha_{20.7} SP_{31}^{(t-1)} + \alpha_{20.8} SP_{32}^{(t-1)})/(\gamma_{31} SP_{31}^{(t-1)} + \gamma_{32} SP_{32}^{(t-1)})$$

$$\left.\begin{array}{l} e_{52}, e_{53}, e_{54} \\ e_{65} \\ e_{76} \\ e_{82}, e_{83}, e_{84} \\ e_{12.2}, e_{12.3}, e_{12.4}, e_{12.5}, e_{12.6} \\ e_{14.2}, e_{14.3}, e_{14.4} \\ E_4, E_5 \end{array}\right\} \text{ are all similarly calculated}$$

In the objective function of the GM-P-3 module, the balance of payments in food and agriculture is maximized using the previous year's world market prices.

In modeling agricultural producers' decisions in HAM-1 the following coefficients are updated using the simulated time horizons:

- yields, expressing the trends of biological development;
- fertilizer use, related to yields;
- feed input coefficients in pork production;
- upper limits of future technologies in the production of agricultural commodities;
- prices and unit wages.

Functions used to update yields and fertilizer inputs are shown in Table 13. The unit pork feed input coefficients are calculated as follows.

TABLE 12 Coefficients for the P-3 module used to calculate module GM-P-3 coefficients in HAM-1.

	Sugarbeet			Corn		Wheat		Pork		Cattle	
	SP_{11}	SP_{12}	SP_{13}	SP_{21}	SP_{22}	SP_{31}	SP_{32}	SP_{41}	SP_{42}	SP_{51}	SP_{52}
	2	3	4	5	6	7	8	9	10	11	12
20 Tractors	$\alpha_{20.2}$	$\alpha_{20.3}$	$\alpha_{20.4}$	$\alpha_{20.5}$	$\alpha_{20.6}$	$\alpha_{20.7}$	$\alpha_{20.8}$				
21 Other equipment	$\alpha_{21.2}$	$\alpha_{21.3}$	$\alpha_{21.4}$	$\alpha_{21.5}$	$\alpha_{21.6}$	$\alpha_{21.7}$	$\alpha_{21.8}$				
22 Pig barns								0.7	0.55		
23 Cattle barns										1	1
24 Other fixed assets	$\alpha_{24.2}$	$\alpha_{24.3}$	$\alpha_{24.4}$	$\alpha_{24.5}$	$\alpha_{24.6}$	$\alpha_{24.7}$	$\alpha_{24.8}$				
25 Labor	$\alpha_{25.2}$	$\alpha_{25.3}$	$\alpha_{25.4}$	$\alpha_{25.5}$	$\alpha_{25.6}$	$\alpha_{25.7}$	$\alpha_{25.8}$	$\alpha_{25.9}$	$\alpha_{25.10}$	$\alpha_{25.11}$	$\alpha_{25.12}$
28 Corn utilization balance				γ_{21}	γ_{22}			$-E^{(t)}_{41}$	$-E^{(t)}_{42}$	$-E_{51}$	$-E_{52}$
Yields	γ_{11}	γ_{12}	γ_{13}	γ_{21}	γ_{22}	γ_{31}	γ_{32}	γ_{41}	γ_{42}	γ_{51}	γ_{52}

TABLE 13 Yield and fertilizer response functions in HAM-1[a].

Crop	Symbol	Yield function	Initial yield tonnes/ha	Fertilizer response function
Sugarbeet				
– present technology	γ_{11}	$\gamma_{11}^{(t)} = \gamma_{11}^{(t-1)} + 0.547$	31.8	$\alpha_{41.11}^{(t)} = 0.01365\gamma_{11}^{(t)} - 0.01607$
– future technology	γ_{12}	$\gamma_{12}^{(t)} = \gamma_{12}^{(t-1)} + 0.533$	42.0	$\alpha_{41.12}^{(t)} = 0.01587\gamma_{12}^{(t)} - 0.0635$
– irrigated production	$\gamma_{13}^{(t)}$	$\gamma_{13}^{(t)} = \gamma_{13}^{(t-1)} + 0.60$	44.0	$\alpha_{41.13}^{(t)} = 0.01875\gamma_{13}^{(t)} - 0.205$
Corn				
– present technology	γ_{21}	$\gamma_{21}^{(t)} = \gamma_{21}^{(t-1)} + 0.132$	4.5	$\alpha_{41.21}^{(t)} = 0.0625\gamma_{21}^{(t)} - 0.08375$
– future technology	γ_{22}	$\gamma_{22}^{(t)} = \gamma_{21}^{(t-1)} + 0.152$	5.5	$\alpha_{41.22}^{(t)} = 0.05782\gamma_{22}^{(t)} - 0.149$
Wheat				
– present technology	γ_{31}	$\gamma_{31}^{(t)} = \gamma_{31}^{(t-1)} + 0.073$	3.3	$\alpha_{41.31}^{(t)} = 0.0909\gamma_{31}^{(t)} - 0.04997$
– future technology	γ_{32}	$\gamma_{32}^{(t)} = \gamma_{32}^{(t-1)} + 0.087$	4.2	$\alpha_{41.32}^{(t)} = 0.08461\gamma_{32}^{(t)} - 0.05536$

[a] $\alpha_{41,ij}^{(t)}$ = unit fertilizer input coefficient in period (t).

– Present technology:

$$E_{41}^{(t)} = E_{41}^{(t-1)} - 0.00333 \qquad (E_{41}^{(0)} = 0.32)$$

– future technology:

$$E_{42}^{(t)} = E_{42}^{(t-1)} - 0.003 \qquad (E_{42}^{(0)} = 0.30)$$

The upper limit of future technology ($Z_i^{(t)}$) is updated as follows:

$$Z_1^{(t)} \text{ (sugarbeet)} = Z_1^{(t-1)} + 0.0375 \qquad (Z_1^{(0)} = 0.25)$$

$$Z_2^{(t)} \text{ (corn)} = Z_2^{(t-1)} + 0.01875 \qquad (Z_2^{(0)} = 0.4)$$

$$Z_3^{(t)} \text{ (wheat)} = Z_3^{(t-1)} + 0.01875 \qquad (Z_3^{(0)} = 0.3)$$

$$Z_4^{(t)} \text{ (pork)} = Z_4^{(t-1)} + 0.035 \qquad (Z_4^{(0)} = 0.3)$$

$$Z_5^{(t)} \text{ (cattle)} = Z_5^{(t-1)} + 0.040 \qquad (Z_5^{(0)} = 0.2)$$

In module P-5 of HAM-1 (food processing) only prices and the wage rate are updated from model coefficients.

3 COMPUTATION OF HAM-1

The computer program of HAM-1 was developed in Hungary by the Computer Center of the Hungarian National Planning Bureau under the leadership of Laszlo Zeöld. At present two program versions exist, allowing us to execute runs both on IIASA's PDP 11/45 computer and on the Hungarian Planning Bureau's ICL-System 4/70.

The computer program of HAM-1 consists of four subprograms:

- LOAD is used to change model parameters, to determine the lengths of runs and to start the program;
- MAIN executes the solutions of the GM-P, GM-A, P, and UD blocks of the model;
- CONSUM executes the solution of the Consumption and Trade block;
- TAB stores selected variables after each simulated year and prepares the outputs including time series for the whole simulated period.

At the end of the computation various types of output can be printed out. The output system of HAM-1 consists of the following three major elements.

Annual results provide the analysis of time periods containing very detailed results for each simulated year and for each module of the model including the updated model coefficients.

The summary of results covers time series of the most important indicators, making possible the global analysis of the various runs.

Plotter output can be prepared for the most important time series, visualizing trends and tendencies projected by HAM-1 and helping in the comparison of various runs.

The summary of results is the most useful type of output and in most cases the information needs on the individual runs can be satisfied on the basis of it. Of course, the more detailed analysis or debugging can only be done using the annual results. The summary of results is structured according to eight tables as follows.

1. Commodity coverage: list of commodities.

2. General indicators: general indicators of production, foreign trade, investment, income development on current and fixed prices for the whole simulated period, and indexes of the development.

3. Dynamics of production and trade: the planned and actual production, and the export or import of individual commodities in physical units.

4. Dynamics of per capita consumption: private consumption by commodities in value.

5. Dynamics of investments: the investments in physical units by types of investment and the share of the rest of the economy in the total investment fund for each year.

6. Dynamics of prices: producer, consumer and world market prices of commodities, and producer and consumer price indexes.

7. Resources and production structure: main physical resources, production structure in physical units and structure of the gross production value of food and agriculture for each or for the desired – e.g. first and last – simulated years.

Figure 20 shows the structure the output system of HAM-1.

4 EXPERIMENTS WITH HAM-1

To realize our objectives with HAM-1 as stated in Section 1, numerous runs of HAM-1 were executed. These runs represent three types of investigation, namely:

- testing the operation of the whole system and investigating the model's relation to reality;
- studying the impacts of changes in external conditions;
- investigating how the system reacts to modifications within the model.

The largest number of runs was of the first of the above-mentioned three types. Some of them simply served debugging purposes. In other cases the sensitivity of the crucial parameters was investigated. Finally several runs were required to test our assumptions on various decision making procedures. These runs led us to the so-called basic variant of HAM-1, which can be considered the most appropriate description of the present Hungarian food and agricultural system, obviously on the aggregation level and accepting the methodological framework of HAM-1.

We now present some of the results of the computation, first of all to realize our third objective – to prove that the HAM model structure is suitable to provide useful information for decision making and policy analysis. In our analysis the results of twelve independent runs, 1–5 and 9–15, are used and compared. These basic model variants are as follows.

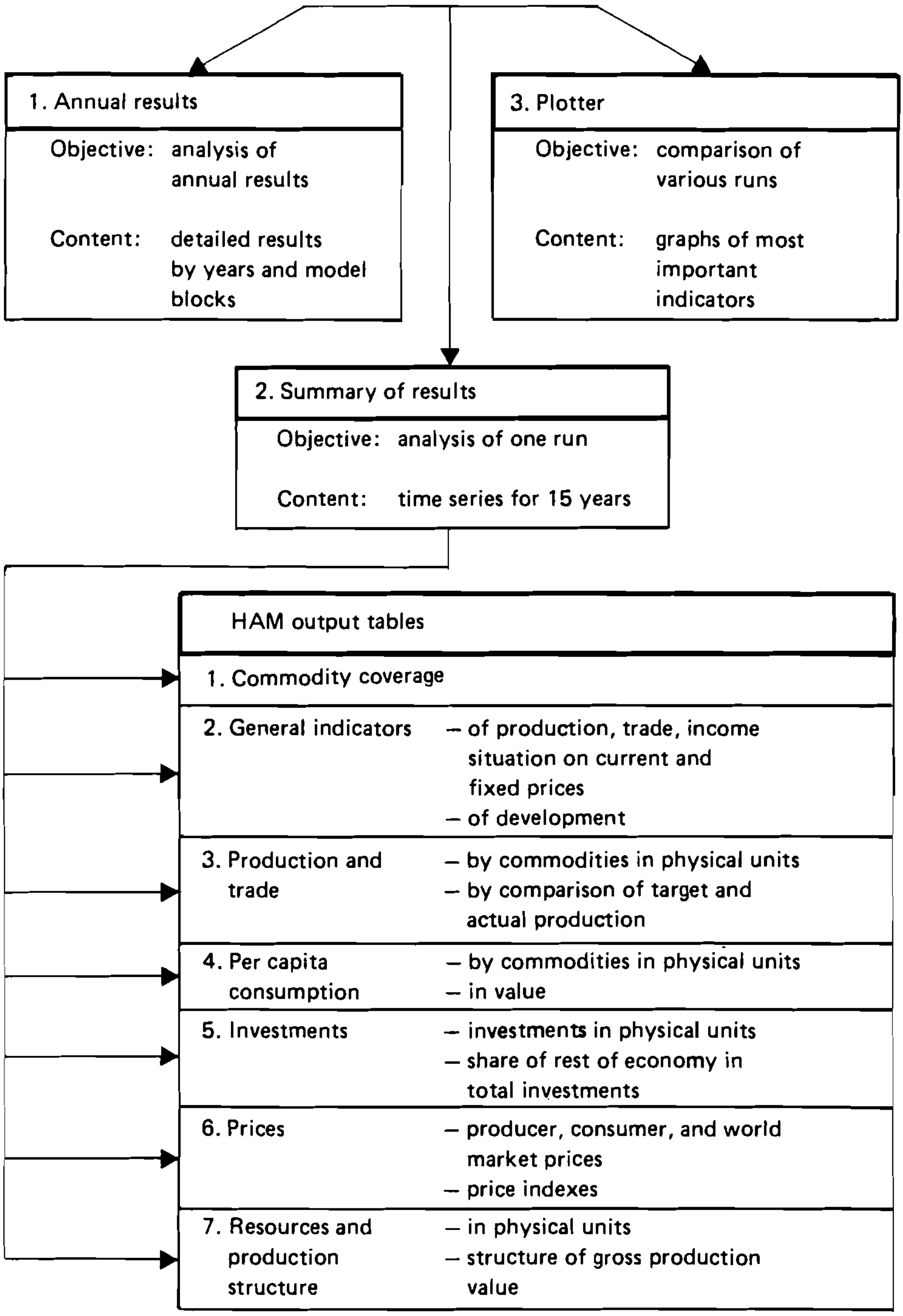


FIGURE 20 Output system of HAM-1.

Variant 1: we assume a three-year price cycle for corn on the world market.

Variant 2: we assume a two-year price cycle for corn on the world market.

Variant 3: the world market prices of all food and agricultural commodities of HAM-1 change year by year.

Variant 4: changing world market prices of variant 3 are used also as domestic producer prices using an exchange rate of 1 US$ = 30 Hungarian forints.

Variant 5: as for variant 4 but using an exchange rate of 1 US$ = 60 Hungarian forints.

Variant 9: 40% of the amortization funds of enterprises in food and agriculture and 50% of the same funds from the rest of the economy are centralized by the government.

Variant 10: the initial value of Z_i (upper limit of the application of advanced technology) is increased.

Variant 11: as for variant 10 but also allowing a faster full substitution of traditional technologies.

Variant 12: as for the basic variant but assuming that domestic prices remain unchanged for the entire time horizon covered.

Variant 13: as for variant 3 but assuming that domestic prices remain unchanged for the entire time horizon covered.

Variant 14: the required level of self-sufficiency from food and agricultural commodities is only 70% instead of 100%.

Variant 15: instead of 100% there is no required level of self-sufficiency in food and agricultural commodities.

As can be seen in the case of variants 1, 2 and 3, the external conditions are modified; in variants 4–15 it is our assumptions about the system that are changed (the model structure is modified).

The impacts of various government policies and external conditions on the development of the whole Hungarian food and agricultural production, as computed by HAM-1, are shown in Figs. 21, 22 and 23. As can be seen in Fig. 21, where the results for the basic variant are compared with those for variant 2, the cyclical change of corn world market prices does not significantly influence the basic trend of production growth. However, the changes in basic government policies – modification of the producer price system or of the desired level of self-sufficiency – have a significant impact on projected production growth. In Fig. 22 the basic variant is compared with variants 4 and 14. The reduction of the desired level of self-sufficiency (variant 14) makes possible a faster growth in production, allowing a higher level of specialization in the direction of commodities with the most favorable production indicators. The use of world market prices as producer prices (variant 4) slows down the development of production, but it will be shown later that this policy is the most efficient from the point of view of the balance of payments.

In Fig. 23, where the basic variant is compared with variant 12, the impacts of the use of fully fixed domestic prices on the development of food and agriculture can be seen.

The impacts of various government policies on the projected positive balance of payments for food and agriculture and other general performance indicators of the system can also be analyzed. Figure 24 shows the balance of payments situation for three model variants – the basic variant and variants 4 and 14. It is obvious that variant 4 is the most favorable from this point of view. However, the results also indicate that a basic modification of the producer price system – a shift to world market prices – may cause serious difficulties within the system during the first few years. The same result is confirmed by variant 5,

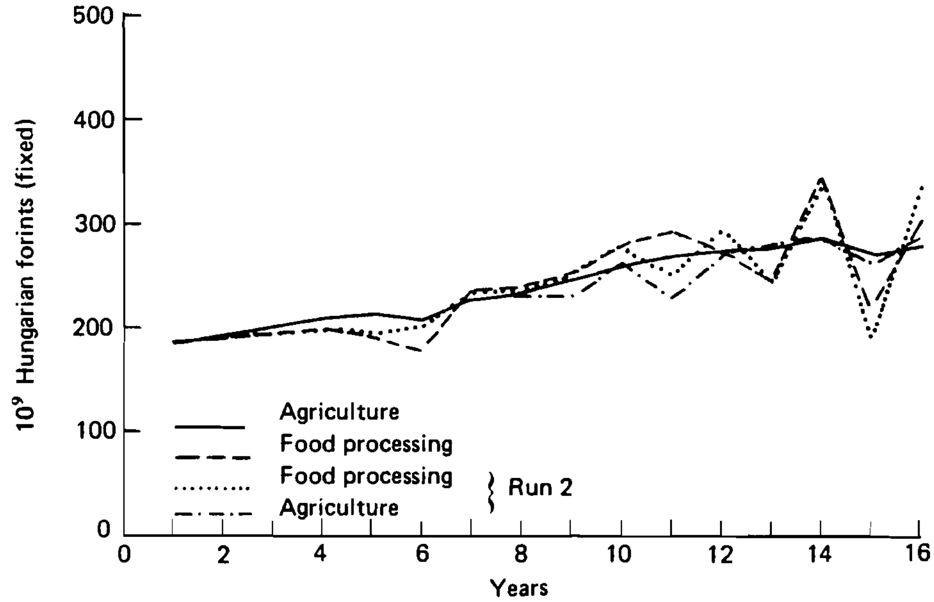


FIGURE 21 Production development projected by HAM-1.

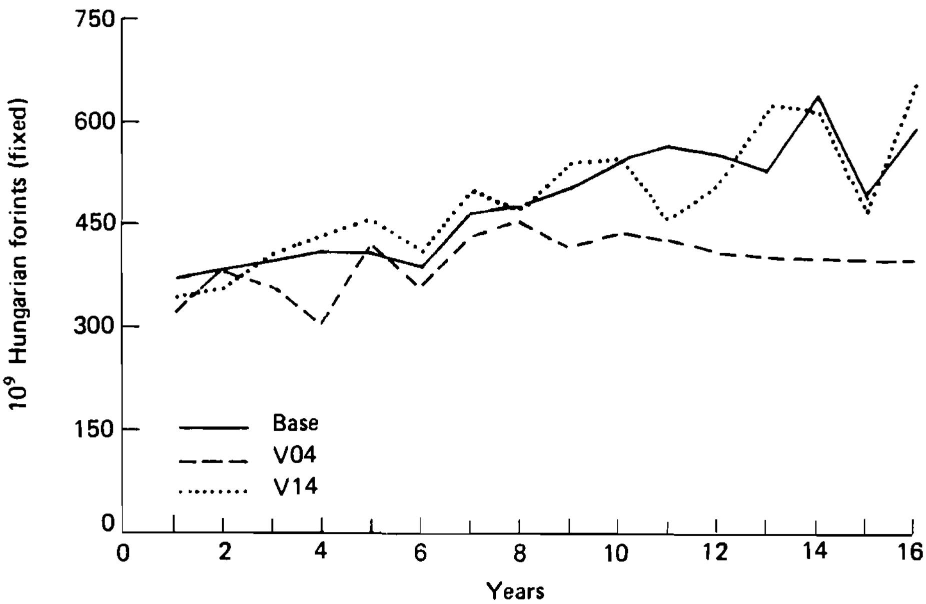


FIGURE 22 GNP in food and agriculture projected by HAM-1.

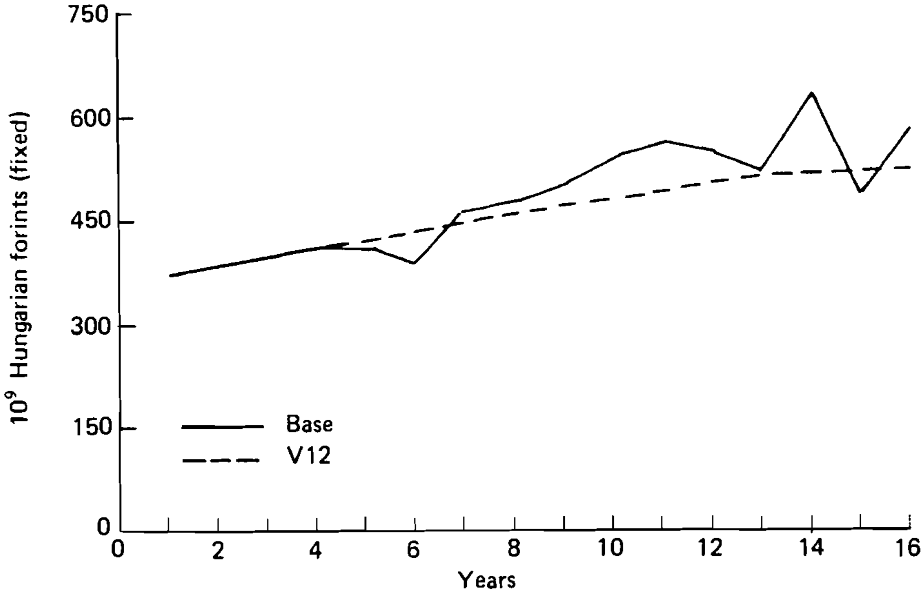


FIGURE 23 GNP in food and agriculture projected by HAM-1.

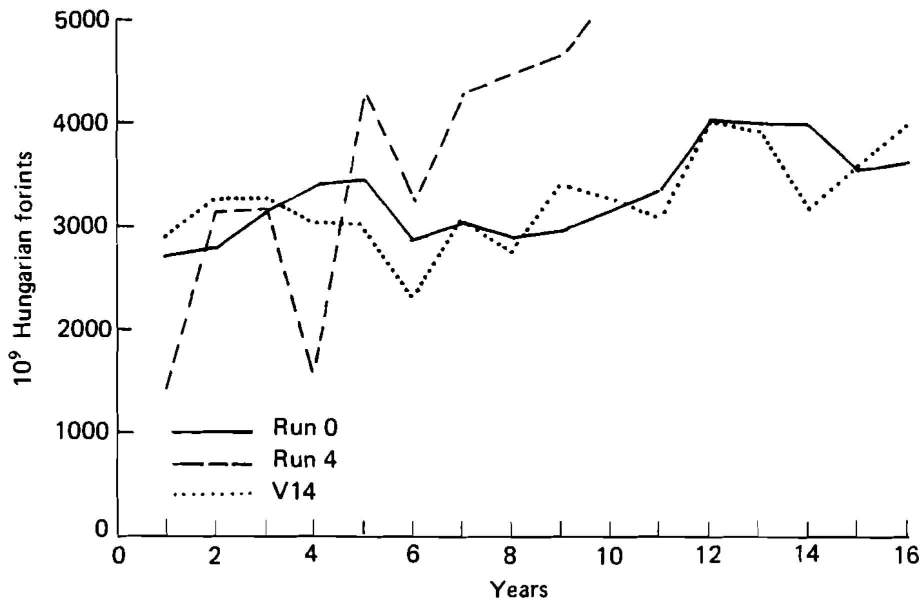


FIGURE 24 Balance of payments projected by HAM-1.

for which we were unable to obtain a feasible solution, indicating that a drastic producer price change requires the additional modification of other elements of the system. Of course, all other performance indicators of the system can be analyzed in a similar way.

Figure 25 presents a comparison of the present structure with the structure of food and agricultural production at the end of the modeled planning horizon as computed by various model variants. Obviously, the application of different government policies leads to different production structures and the structure is also influenced by changing external conditions, especially world market prices. The main conclusion of Fig. 14 is that a more specialized structure of food and agriculture is desirable from an economic point of view. With various assumptions a large number of possible structural developments can be computed, and by using this information there is no doubt that a model like HAM-1 can be a very useful tool in structural decision making.

The descriptive character of HAM's structure enables the investigation of the efficiency of the whole economic management system as well as of the individual instruments. In Fig. 26 the example of corn shows how actual production is related to government plan targets. Figure 16 illustrates very clearly how world market prices influence the production in the modeled system. There is a two-year lag between world market prices and producers' reactions.

The efficiency of the individual policy instruments of the government may also be analyzed on the basis of HAM. Variants 4, 5, 12 and 13 represent situations in which the domestic pricing mechanism is modified. In Figs. 22, 23 and 24 the impacts of these changes on the overall growth and balance of payments situation are clearly discernible.

On the basis of the HAM model structure, a wide range of investigations can be made in connection with the individual commodities. Figure 27 shows the production of corn in relation to world market and producer prices computed by variant 2. It can be seen that the adjustment mechanism build into HAM-1 is efficient in the case of two-year price cycles (variant 2). Domestic production increases when international market conditions are most favorable and decreases in parallel with world market prices. It is also possible to quantify the extent of price reaction of individual commodities.

The production module of HAM allows us to carry on various investigations in relation to the technological development of food and agriculture. Variants 12 and 13 represent some examples of this kind of investigation. In Fig. 28, the share of advanced technology in total production is shown for the cases of sugar beet and corn for the basic variant. The investment programs associated with various government policies can obviously also be analyzed.

The HAM model structure is suitable for various investigations of consumption by the population. The aggregated commodity coverage of HAM-1 does not allow us to go into detail with regard to the structure of consumption. However, as Fig. 29 shows, the impacts of various government policies on consumption can be analyzed.

The interrelation between indirect and drain effects within the system can also be studied. For example, in Figs. 30 and 31 the wheat and sugarbeet production are shown for the basic variant. The sudden increase in year 6 of the wheat production seems to have been unexpected, especially because the producer price remained unchanged from year 5 to year 6. This can be explained on the basis of comparisons with the developments in sugarbeet production. The production of sugarbeet decreased very sharply from year 5 to year 6 and this crop was partly replaced by the more profitable wheat. This increase is not desired in the national plan; producer prices are thus modified and wheat loses its competitiveness.

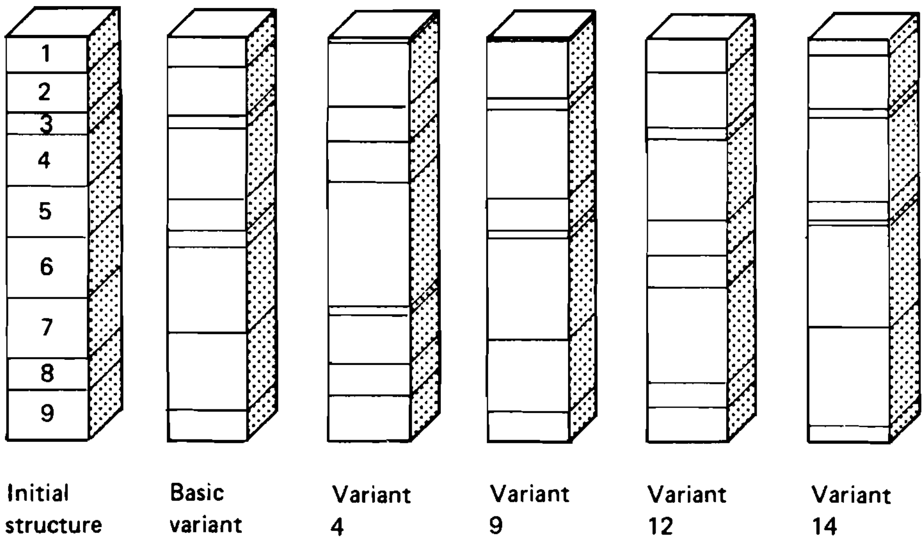


FIGURE 25 Structure of food and agricultural production. 1, sugarbeet; 2, corn; 3, wheat; 4, pigs; 5, cattle; 6, sugar; 7, pork; 8, processed meat; 9, beef.

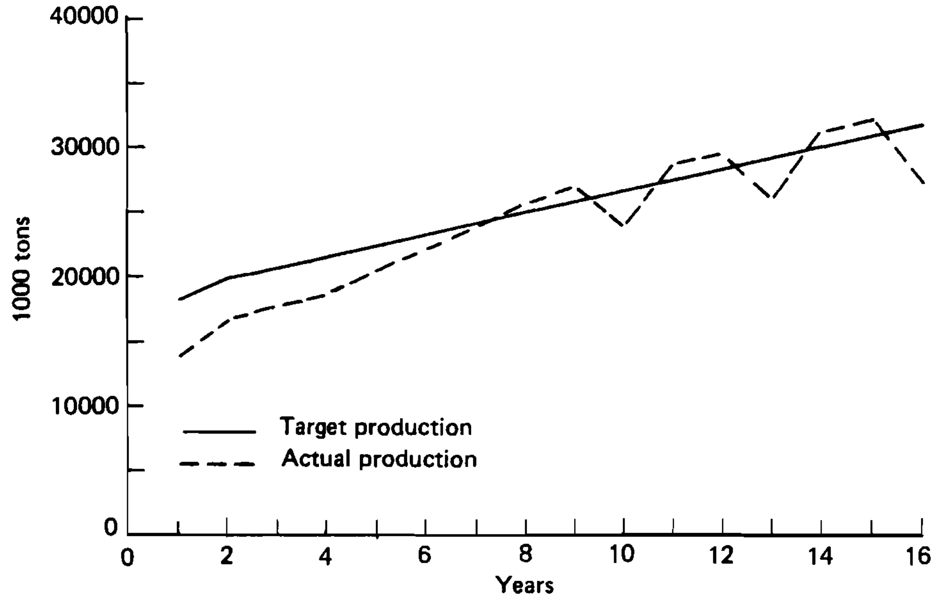


FIGURE 26 Production and trade of corn (run 0). (Results from HAM-1.)

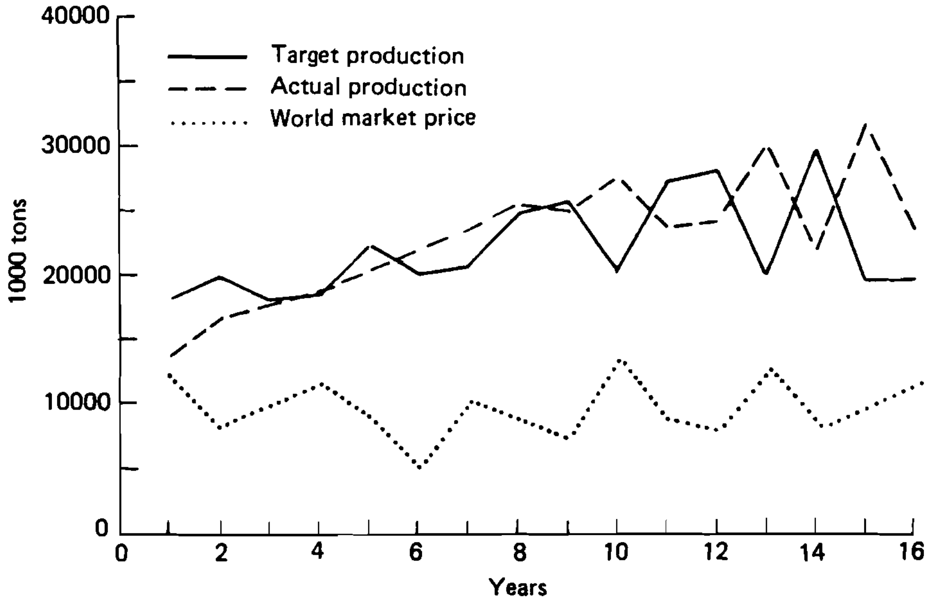


FIGURE 27 Production of corn (run 2). (Results from HAM-1.)

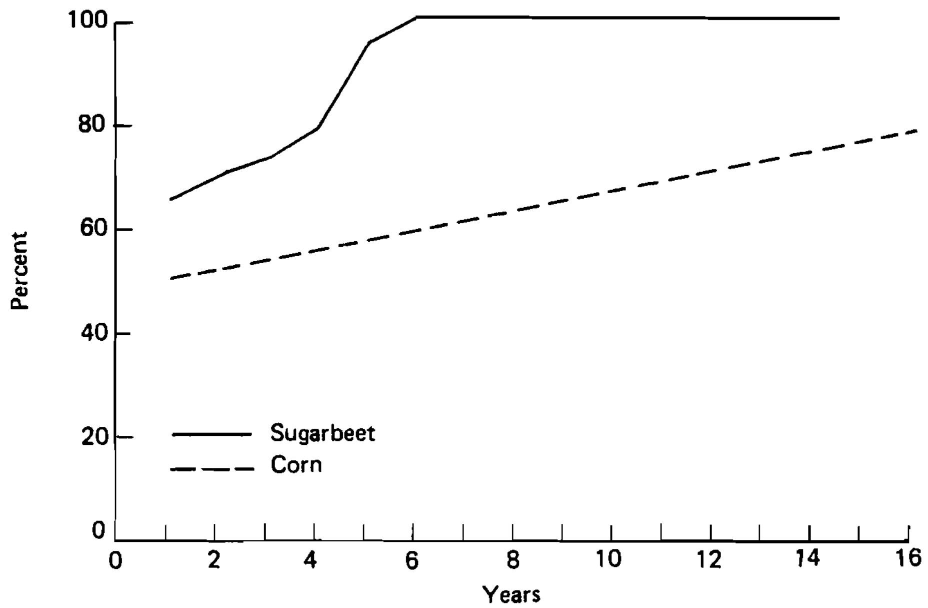


FIGURE 28 Share of advanced technology in total production (run 0). (Results form HAM-1.)

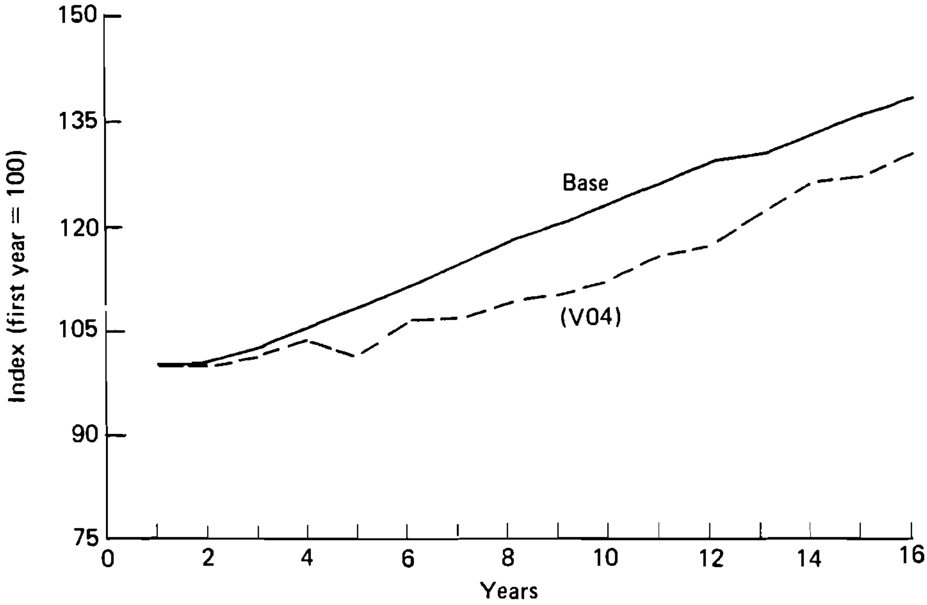


FIGURE 29 Dynamics of consumption projected by HAM-1.

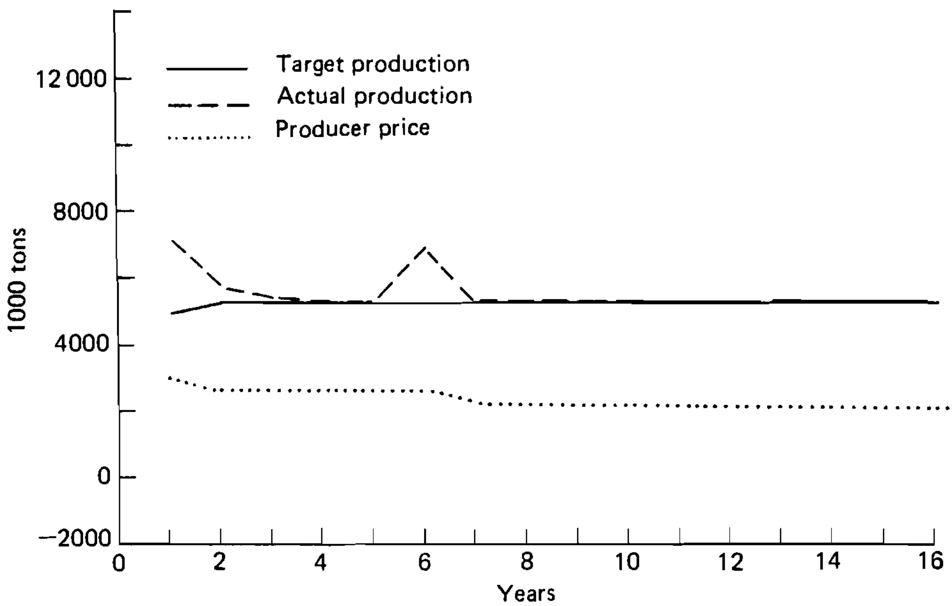


FIGURE 30 Production of wheat (run 0). (Results from HAM-1.)

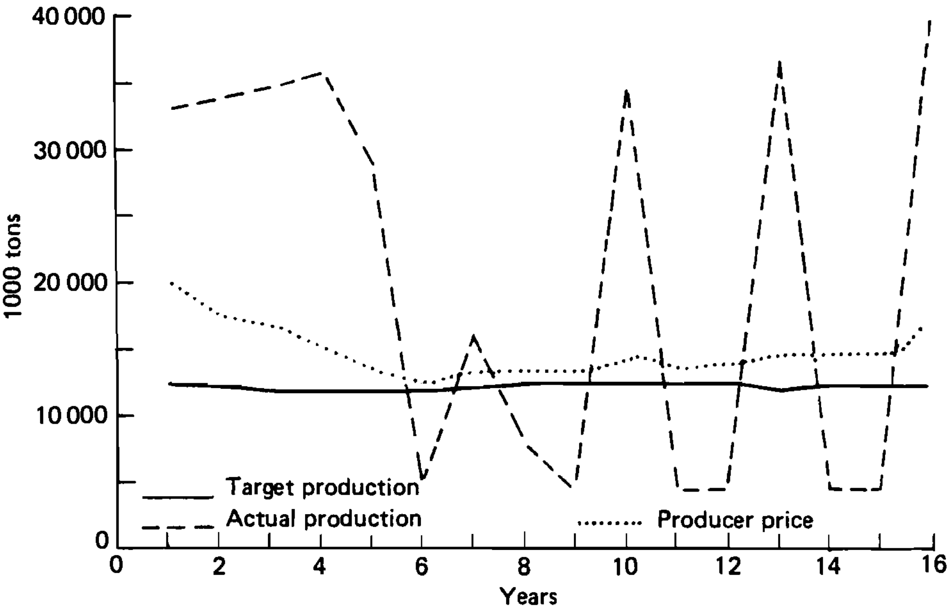


FIGURE 31 Production of sugarbeet (run 0). (Results from HAM-1.)

5 CONCLUSIONS OF THE HAM-1 EXPERIMENT

On the whole we felt that the development of HAM-1 was a very useful step in our work towards the final version of HAM. We believe that the results of various runs of HAM-1 were fairly promising. They supported the appropriateness of our approach and they prove that the structure of the HAM model really can contribute to the further development of planning techniques and also to actual decision making. HAM-1 also led us to several methodological conclusions that are very important for the further refinement of the model. The most important ones are as follows.

- A relatively aggregated commodity coverage, as in the case of HAM-1, is also suitable for very valuable investigations, and above a relatively moderate level the disaggregation does not improve the quantity of information generated by macromodels. The commodity aggregation of the final version of HAM, contrary to our original plans, will therefore follow the commodity list of the Food and Agriculture Program at IIASA, having not more than 10–15 additional commodities.
- The GM-A model describing the activity of the government in revising policy instruments is the crucial part of the model from the point of view of further refinement. Further investigations are required to analyze the present practice and in particular the pricing mechanism built into the model has to be revised.
- The use of linear programming in three modules caused less difficulty than we expected. In spite of this, we shall try to substitute the linear programming model

of agricultural producer decisions with a more sophisticated nonlinear programming approach. The structure of the remaining LPs will also be further developed on the basis of HAM-1.

- More attention has to be given to the dynamic features of agricultural investments. The approach of HAM-1, which is to include these decisions in production models, is not fully satisfactory for some of the investments (e.g. the development of animal husbandry). The application of a separate multistage model for investment decisions seems to be the desired solution.
- The enlargement of the model size requires a well-designed data collection system, but we have to be aware of the fact that owing to insufficient information some of the parameters cannot be estimated by statistical methods. In these cases we intend to use the estimations of experts at various Hungarian research institutions.
- The elaboration of further methods of validation for HAM-1 has to be one of our most important tasks in the future.

PART THREE

Final Version of the Hungarian Agricultural Model (HAM-2)

1 OBJECTIVES, COMMODITY COVERAGE, AND DATA BASE OF HAM-2

Using the experience gained with HAM-1, a more detailed version of HAM, HAM-2 was developed.

Besides satisfying the common requirements of IIASA's food and agricultural models, HAM-2 was constructed to be useful in investigating major developmental problems in Hungarian food and agriculture. Therefore, in the disaggregation of food and agriculture, the specific requirements of the potential model users were also considered. HAM-2 actually has a more detailed commodity coverage than other FAP models. First, agricultural raw materials and processed food commodities are handled separately according to the two main sectors of food prodcution in the model. Table 14 contains the list of commodities

TABLE 14 Commodity coverage of HAM-2.

Agriculture	Food processing
1 Food grains	22 Flour
2 Coarse grains except corn	23 Bran
3 Corn	24 Vegetable oils
4 Oil seeds	25 Oil cake
5 Sugarbeet	26 Beef
6 Green fodders	27 Pork
7 Potatoes	28 Lamb
8 Vegetables	29 Slaughtering wastes/offal
9 Other field crops	30 Processed meat (high moisture content)
10 Fruits	31 Processed meat (low moisture content, smoked, canned)
11 Grapes	32 Poultry meat (processed)
12 Beef cattle	33 Processed eggs
13 Dairy cattle	34 Slaughtering wastes/offal (poultry)
14 Pigs	35 Dairy products
15 Sheep meat	36 Milk powder
16 Wool	37 Protein feeds
17 Poultry meat	38 Feed mix
18 Eggs	39 Sugar
19 Other animal husbandry	40 Canned fruits
20 Alfalfa for drying	41 Canned vegetables
21 Additional farm activities	42 Wine
	43 Other processed foods
	44 Coffee
	45 Tea, cocoa
	Rest of the Economy
	46 *n*th commodity

considered in HAM-2. Hungarian agricultural production is covered by 21 commodities. Most of the agricultural commodities represent a group of products (e.g. food grains or fruits) and under "other field crops" and "other animal husbandry" the rest of the production not individually represented is aggregated. The commodity "additional farm activities" such as construction and servicing done by the farms. These activities do not belong naturally with agriculture, but in the Hungarian situation they are so interlinked with agriculture that their aggregation with the rest of the economy would greatly complicate the modeling of agriculture. (They are based on the labor force and resources of agriculture, the income generated by these activities being mostly invested in agriculture.) The commodity coverage of the household and private agriculture module (P-1) is somewhat narrower than that of the socialist agriculture module (P-2).

The 24 processed food commodities in HAM-2 express the present structure of the Hungarian food processing industry. In the selection of commodities the commodity classification of the Hungarian National Planning Bureau was used as the major guideline. (Table 14 lists the processed commodities.) Of the 24 commodities, 22 are related to raw materials domestically produced. Coffee, tea, and cocoa are imported as raw materials and are further processed, mainly only packed.

The 46th commodity is related to the remainder of the economy, aggregating all the rest of the economy including production and services.

The data base of HAM-2 includes various sources. Statistical data available from the Central Statistical Bureau and from the Ministry of Food and Agriculture were primarily utilized. We relied on UN Food and Agriculture Organization data tapes for international prices. The trends of biological and technological development, the overall targets for the growth of the economy, and other previous government decisions constraining agricultural development were supplied by experts from the National Planning Bureau and the Research Institute for Agricultural Economics. In estimating technological coefficients the major indicators of existing production systems were considered. Obviously, the level of aggregation in the Production module does not allow us to be very detailed in respect of production technologies. The main data base for parameters in production models was from the annual statistical survey of the Research Institute for Agricultural Economics and the Center for Statistical and Economic Analysis at the Ministry of Food and Agriculture on inputs and expenses of various commodities. Estimates from the Farm Machinery Research Institute were also considered. The algorithm for revising government policy instruments was developed on the basis of interviews with high level officials and information supplied by the Ministry of Finance.

2 DESCRIPTION OF HAM-2

HAM-2 describes Hungarian food and agriculture in a rather disaggregated way. HAM-2 is practically structured according to our general model outline discussed in Part 1. In comparison with the general description, only one simplification is applied: random effects of weather on agricultural production are not directly included. Otherwise, HAM-2 is formulated as shown in Fig. 1.

2.1 Government Economic Planning Submodel

According to the general model structure, the GM-P submodel of HAM-2 incorporates four modules. The most important element of GM-P block is the third module, which is actually a linear programming model to fix government targets for food and agriculture.

In the GM-P-3 module of HAM-2 commodities are considered according to Table 3. Production sectors are not treated separately. The LP model actually consists of 75 variables and 63 constraints. In addition to variables representing the production of various commodities, 29 variables are related to exports and 11 to imports of food and agricultural commodities. Of the 63 constraints, 26 are connected with resources, 34 are commodity balances and 3 express overall economic requirements for food and agriculture (e.g. lower bounds for the gross national product of food and agriculture). The maximum efficiency of agricultural foreign trade was considered as a major objective of central planners and this is described by the objective function. The impacts of an alternative objective function, namely the maximization of foreign exchange earnings from food and agriculture, is also investigated. Table 15 gives an overview of the structure of the linear programming model built into the GM-P-3 module of HAM-2.

2.2 Production Block

The first module of the Production Block is devoted to the private and household sector of Hungarian agriculture. The parameters of supply functions used to describe the behavior of this sector have been estimated based on the time series of 1964–76. Table 16 gives full information on crops and animal products considered in module P-1 (eleven crop and eight animal products). The suitability of parameters of the supply function was verified by statistical methods.

The calculations related to expenses of household and private agricultural production are based on the following:*

$$HDES^{(t)} = \alpha_9 HD_1^{(t)} IKT_1^{(t)} + \alpha_{12} HD_2^{(t)} IKT_2^{(t)} + \alpha_{15} HD_3^{(t)} IKT_3^{(t)}$$

$$HWES^{(t)} = \alpha_{10} HD_1^{(t)} IKT_1^{(t)} + \alpha_{13} HD_2^{(t)} IKT_2^{(t)} + \alpha_{16} HD_3^{(t)} IKT_3^{(t)}$$

$$HMI^{(t)} = \alpha_{11} HD_1^{(t)} IKT_1^{(t)} + \alpha_{14} HD_2^{(t)} IKT_2^{(t)} + \alpha_{17} HD_3^{(t)} IKT_3^{(t)}$$

$$IKTO^{(t)} = HD_1^{(t)} IKT_1^{(t)} + HD_2^{(t)} IKT_2^{(t)} + HD_3^{(t)} IKT_3^{(t)}$$

Expenses of material inputs:

$$MEHI^{(t)} = PMUTR^{(t)} HD_{10}^{(t)} + HD_{11}^{(t)}$$

$$\begin{aligned} MEH^{(t)} = {} & IKTO^{(t)} + (HD_6^{(t)} + HBF_6^{(t)}) P_6^{\mathrm{pr}(t)} + p_3^{\mathrm{pr}(t)} HBF_3^{(t)} + p_{38}^{\mathrm{pr}(t)} HD_7^{(t)} \\ & + p_8^{\mathrm{pr}(t)} HD_1^{(t)} + p_7^{\mathrm{pr}(t)} HD_9^{(t)} + p_{11}^{\mathrm{pr}(t)} HBF_{11}^{(t)} + p_2^{\mathrm{pr}(t)} HD_4^{(t)} \\ & + p_3^{\mathrm{pr}(t)} HD_5^{(t)} + MEHI^{(t)} \end{aligned}$$

*The symbols are explained in the Appendix.

TABLE 15 Structure of the linear programming model included in the GM-P-3 module in HAM-2.

	Constraints	Variables					Relation	Right-hand side
		Production agriculture		Food processing	Export variables	Import variables		
		Plant production	Animal husbandry					
		PPN_i^t	PP_l^t	PPN_i^t	PE_i^t	PI_i^t		
1	Objective functions				cp_i^t	$-cp_i^{t'}$	→	
2–14	Resource constraints in agriculture	$a_{ki}^{\bar{s}(t)}$	$a_{kl}^{\bar{s}(t)}$				⩽	$LS_1^t + LS_2^t + LSH^t$ $SKAPT_k^t + HKAPT_k^t$ $PSLF^t + HL^t$
15–26	Resource constraints in food processing			$a_{ki}^{\bar{p}}$			⩽	$KAPT_k^t$
27–44	Commodity balance in agriculture	1	$s_{il}^{\bar{t}}$	$-1/\gamma p_i$	−1	+1	⩾	$PTC_i^t + PTCG_i^t + TCS_i^{t-1} + PSE_i^t - PSI_i^t$
45–60	Commodity balance in food processing	1	$-a_{il}^{\bar{s}(t)}$	1	−1	+1	⩾	
62	Gross production value	$p_i^{\mathrm{pr}(t)}$	$s_{il}^{\bar{t}} p_i^{\mathrm{pr}(t)}$	$p_i^{\mathrm{pr}(t)}$			=	$DGNPA^t$
63	Balance of foreign payments				$p_i^{\mathrm{w}(t)}$	$-p_i^{\mathrm{w}(t)}$	=	$DPBA^t$
61 64–92	Export constraints				1		⩽	PTK_i^t

TABLE 16 Variables related to production and their symbols in the production block of HAM-2.

Branch product	Technological alternative considered	Scale of the crop	Total production	Output from sector	Household production
	Value or physical unit		Tonnes, head, or value		
Agriculture					
Feed grain production	*SPT*011 *SPT*012	*SP*01			
1 Feed grain			*SPN*01	*SPA*01	*HP*01
Coarse grain production	*SPT*021 *SPT*022	*SP*02			
2 Coarse grain			*SPN*02	*SPA*02	
Corn production	*SPT*031 *SPT*032	*SP*03			
3 Corn			*SPN*03	*SPA*03	*HP*03
Oil crop production	*SPT*041 *SPT*042	*SP*04			
4 Oil seeds			*SPN*04	*SPA*04	
Sugarbeet production	*SPT*051 *SPT*052 *SPT*053	*SP*05			
5 Sugarbeet			*SPN*05	*SPA*05	
Green feed production	*SPT*061 *SPT*062 *SPT*063 *SPT*064 *SPT*065 *SPT*066	*SP*06			
6 Green fodder			*SPN*06	*SPA*06	*HP*06
Potato production	*SPT*071 *SPT*072 *SPT*073	*SP*07			
7 Potatoes			*SPN*07	*SPA*07	*HP*07
Vegetable production	*SPT*081 *SPT*082	*SP*08			
8 Vegetables			*SPN*08	*SPA*08	*HP*08
Other field crop production	*SPT*091 *SPT*092	*SP*09			
9 Other field crops			*SPN*09	*SPA*09	*HP*09
Fruit production	*SPT*101 *SPT*102	*SP*10			
10 Fruits			*SPN*10	*SPA*11	*HP*11
Grape production	*SPT*111 *SPT*112	*SP*11			

TABLE 16 (*continued*)

Branch product	Technological alternative considered	Scale of the crop	Total production	Output from sector	Household production
	Value or physical unit		Tonnes, head, or value		
11 Grapes			*SPN*11	*SPA*11	*HP*11
Cattle production	*SPT*121 *SPT*122 *SPT*123 *SPT*124	*SP*12			
12 Beef			*SPN*12	*SPA*12	*HP*12
13 Milk			*SPN*13	*SPA*13	*HP*13
Pig production	*SPT*141 *SPT*142	*SP*14			
14 Pork			*SPN*14	*SPA*14	*HP*14
Sheep production	*SPT*151 *SPT*152 *SPT*153	*SP*15			
15 Lamb			*SPN*15	*SPA*15	*HP*15
16 Wool			*SPN*16	*SPA*16	*HP*16
Poultry production	*SPT*171 *SPT*172 *SPT*173 *SPT*174	*SP*17			
17 Poultry meat			*SPN*17	*SPA*17	*HP*17
18 Eggs			*SPN*18	*SPA*18	*HP*18
Other animal husbandry	*SPT*191 *SPT*192	*SP*19			
19 Other animal products			*SPN*19	*SPA*19	*HP*19
Feed dehydrating	*SPT*201	*SP*20			
20 Alfalfa pellets			*SPN*20	*SPA*20	
Additional activities	*SPT*211	*SP*21			
21 Service of additional activities			*SPN*21	*SPA*21	
Food processing					
Milling industry		*FP*22			
22 Flour			*FPN*22	*FPA*22	
23 Bran			*FPN*23	*FPA*23	
Oil seed processing		*FP*24			
24 Vegetable oil			*FPN*24	*FPA*24	
25 Oil cake			*FPN*25	*FPA*25	
Meat industry		*FP*26			

TABLE 16 (*continued*)

Branch product	Technological alternative considered	Scale of the crop	Total production	Output from sector	Household production
	Value or physical unit		Tonnes, head, or value		
26 Beef			*FPN*26	*FPA*26	
27 Pork			*FPN*27	*FPA*27	
28 Lamb			*FPN*28	*FPA*28	
29 Slaughtering wastes, offal			*FPN*29	*FPA*29	
30 Processed meat, high moisture content			*FPN*30	*FPA*30	
31 Processed meat, smoked			*FPN*31	*FPA*31	
Poultry industry		*FP*32			
32 Processed poultry meat			*FPN*32	*FPA*32	
33 Processed eggs			*FPN*33	*FPA*33	
34 Slaughtering wastes (poultry)			*FPN*34	*FPA*34	
Dairy industry		*FP*35			
35 Dairy products			*FPN*35	*FPA*35	
36 Milk powder			*FPN*36	*FPA*36	
Protein feed production		*FP*37			
37 Protein feeds			*FPN*37	*FPA*37	
38 Feed mix			*FPN*38	*FPA*38	
Sugar industry		*FP*39			
39 Sugar			*FPN*39	*FPA*39	
Canning industry		*FP*40			
40 Canned fruits			*FPN*40	*FPA*40	
41 Canned vegetables			*FPN*41	*FPA*41	
Wine industry		*FP*42			
42 Wine			*FPN*42	*FPA*42	
Other Food Processing		*FP*43			
43 Other processed food			*FPN*43	*FPA*43	

In HAM-2 the production activities of state and cooperative farms are represented by a relatively wide range of variables, as shown in Table 16. The available resources and resource utilization are considered using 19 constraints. Product utilization is described by 21 equations. In the P-2 module the linear programming model includes at least two

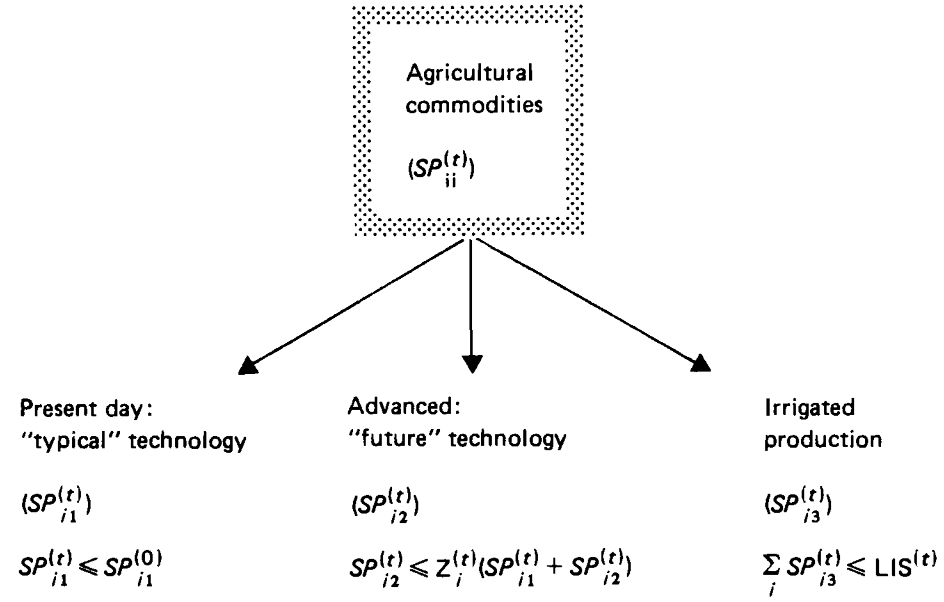


FIGURE 32 Technological change in HAM.

production technologies for each commodity (see Fig. 32). Relatively wide ranges of resources and input factors are considered, as shown in Table 17, and changes in production structure are constrained by upper and lower bounds that are partly updated annually and partly given exogenously.

As has been mentioned, HAM-2 does not include module P-3. Methods for considering weather conditions have not yet been developed within the Food and Agriculture Program. The routines applied, if necessary, to distribute products between processing and consumption are included in module P-4.

In module P-4 of HAM-2 the production program of the food processing industry is calculated according to the major branches of the industry. This procedure is based on the following equations.

(a) Milling industry*:

$$FELH^{(t)}_{1} = (1/\gamma_1)(PTC^{(t)}_{22} + PTCG^{(t)}_{22} + \gamma_{28} FPN^{(t-1)}_{43})$$

$$FPN^{(t)}_{22} = PTC^{(t)}_{22} + PTCG^{(t)}_{22} + \gamma_{28} FPN^{(t-1)}_{43}$$

$$FPN^{(t)}_{23} = \gamma_2 FELH^{(t)}_{1}$$

$$KAPIG^{(t)} = FELH^{(t)}_{1}$$

*The symbols are explained in the Appendix.

TABLE 17 Production resources and inputs in HAM.

Crop production	Animal husbandry	Food processing
Land – Plowland – Pastures and meadows – Irrigated land – Plantations Machinery – Tractors – Other equipment Buildings Labor Materials and services – Fertilizer – Pesticides – Other industrial materials and non-agricultural services – Materials of agricultural origin	Buildings – Stables – Other buildings and equipment Labor Materials – Feeds – Other agricultural materials – Industrial materials and services	Processing facilities Labor Materials – Agricultural raw materials – Industrial materials and services

(b) Vegetable oil processing:

$$FELH_4^{(t)} = SPN_4^{(t)} - PE_4^{(t)}$$

$$FPN_{24}^{(t)} = \gamma_3 FELH_4^{(t)}$$

$$FPN_{25}^{(t)} = \gamma_4 FELH_4^{(t)}$$

$$KAPIG_2^{(t)} = FELH_4^{(t)}$$

(c) The meat industry is modeled according to two levels of processing. Firstly slaughtering and primary meat processing is described:

$$FELH_{12}^{(t)} = SPN_{12}^{(t)} + HP_{12}^{(t)} - PE_{12}^{(t)}$$

$$FPN_{26}^{(t)} = \gamma_5 FELH_{12}^{(t)}$$

$$FELH_{14}^{(t)} = SPN_{14}^{(t)} + HP_{14}^{(t)} - TCS_{14}^{(t)} - PE_{14}^{(t)}$$

$$FPN_{27}^{(t)} = \gamma_6 FELH_{14}^{(t)}$$

$$FELH_{15}^{(t)} = SPN_{15}^{(t)} + HP_{15}^{(t)} - PE_{15}^{(t)}$$

$$FPN_{28}^{(t)} = \gamma_7 FELH_{15}^{(t)}$$

$$KAPIG_3^{(t)} = FELH_{12}^{(t)} + FELH_{14}^{(t)} + FELH_{15}^{(t)}$$

$$FPN_{29}^{(t)} = \gamma_8 FELH_{12}^{(t)} + \gamma_9 FELH_{14}^{(t)} + \gamma_{10} FELH_{15}^{(t)}$$

Then further processing of meat (production of sausages, salami etc.) is threated:

$$FELH_{26}^{(t)} = \alpha_2 FPN_{26}^{(t)}$$

$$FELH_{27}^{(t)} = FPN_{27}^{(t)} - PTC_{27}^{(t)} - PE_{27}^{(t)} - PTCG_{27}^{(t)}$$

$$FPN_{30}^{(t)} = \gamma_{11} FELH_{26}^{(t)} + \gamma_{12} \alpha_3 FELH_{27}^{(t)}$$

$$FPN_{31}^{(t)} = \gamma_{13}(1 - \alpha_3) FELH_{27}^{(t)}$$

$$FELH_{17}^{(t)} = SPN_{17}^{(t)} + HP_{17}^{(t)} - TCS_{17}^{(t)} - PE_{17}^{(t)}$$

$$FPN_{32}^{(t)} = \gamma_{14} FELH_{17}^{(t)}$$

$$FELH_{18}^{(t)} = SPA_{18}^{(t)} + HP_{18}^{(t)} - TCS_{18}^{(t)}$$

$$FPN_{33}^{(t)} = \gamma_{15} FELH_{18}^{(t)}$$

$$FPN_{29}^{(t)} = \gamma_{16} FELH_{17}^{(t)} + FPN_{29}^{(t)}$$

$$KAPIG_4^{(t)} = FPN_{30}^{(t)} + FPN_{31}^{(t)}$$

The wastes in meat processing are determined as follows:

$$KAPIG_5^{(t)} = FPN_{29}^{(t)}$$

$$KAPIG_{16}^{(t)} = FELH_{17}^{(t)}$$

If

$$KAPT_5^{(t)} < KAPIG_5^{(t)}$$

then

$$FPN_{34}^{(t)} = \gamma_{16} KAPT_5^{(t)}$$

$$FELH_{29}^{(t)} = KAPT_5^{(t)}$$

If

$$KAPT_5^{(t)} \geqslant KAPIG_5^{(t)}$$

then

$$FPN_{34}^{(t)} = \gamma_{16} FPN_{29}^{(t)}$$

$$FELH_{29}^{(t)} = FPN_{29}^{(t)}$$

(d) Dairy industry:

$$FELH_{13}^{(t)} = SPA_{13}^{(t)} + HP_{13}^{(t)} - TCS_{13}^{(t)}$$

$$FPN_{35}^{(t)} = \gamma_{17} FELH_{13}^{(t)}$$

$$FPN_{36}^{(t)} = \gamma_{18} FELH_{13}^{(t)}$$

$$KAPIG_{7}^{(t)} = FPN_{35}^{(t)}$$

$$KAPIG_{8}^{(t)} = FPN_{36}^{(t)}$$

(e) Feed industry: the modeling of this branch required a more complicated procedure. First the production of protein feeds is calculated:

$$Y_{1}^{(t)} = KEVTI^{(t)} + HD_{7}^{(t)} - STAKG^{(t)} - SKUK^{(t)} - HD_{14}^{(t)} - HD_{15}^{(t)}$$

$$FPN_{37}^{(t)} = FPN_{34}^{(t)} + FPN_{25}^{(t)} + FPN_{36}^{(t)}$$

If

$$(FPN_{37}^{(t)} + S_{37}^{(t-1)} - Y_{1}^{(t)}) > 0$$

then

$$FELH_{20}^{(t)} = 0$$

Otherwise if

$$(FPN_{37}^{(t)} + S_{37}^{(t-1)} + FPN_{20}^{(t)} + S_{20}^{(t-1)} - Y_{1}^{(t)}) > 0$$

then

$$FELH_{20}^{(t)} = Y_{1}^{(t)} - FPN_{37}^{(t)} - S_{37}^{(t-1)}$$

If

$$(FPN_{37}^{(t)} + S_{37}^{(t-1)} + FPN_{20}^{(t)} + S_{20}^{(t-1)} - Y_{1}) \leq 0$$

then

$$FELH_{20}^{(t)} = FPN_{20}^{(t)} + S_{20}^{(t-1)}$$

$$FELH_{34}^{(t)} = FPN_{34}^{(t)}$$

$$FELH_{25}^{(t)} = FPN_{25}^{(t)}$$

$$FELH_{36}^{(t)} = FPN_{36}^{(t)}$$

$$FPN_{37}^{(t)} = FPN_{37}^{(t)} + FELH_{20}^{(t)}$$

The production of feed mix is described as follows:
If

$$HD_{14}^{(t)} + STAKG^{(t)} > FPN_{23}^{(t)}$$

then

$$FELH_{2}^{(t)} = HD_{14}^{(t)} + STAKG^{(t)} - FPN_{23}^{(t)}$$

and

$$FELH_{23}^{(t)} = FPN_{23}^{(t)}$$

If

$$HD_{14}^{(t)} + STAKG^{(t)} \leqslant FPN_{23}^{(t)}$$

then

$$FELH_{2}^{(t)} = 0$$

$$FELH_{23}^{(t)} = HD_{14}^{(t)} + STAKG^{(t)}$$

$$FELH_{3}^{(t)} = SKUK^{(t)} + HD_{15}^{(t)}$$

$$FPN_{38}^{(t)} = Y_{1}^{(t)} + FELH_{2}^{(t)} + FELH_{3}^{(t)} + FELH_{23}^{(t)}$$

$$FELH_{37}^{(t)} = Y_{1}^{(t)}$$

If

$$Y_{1}^{(t)} - FPN_{37}^{(t)} - S_{37}^{(t-1)} > 0$$

then

$$X_{1}^{(t)} = Y_{1}^{(t)} - FPN_{37}^{(t)} - S_{37}^{(t-1)}$$

otherwise

$$X_1^{(t)} = 0$$

$$KEVTE^{(t)} = X_1^{(t)}\gamma_{20} + FELH_{34}^{(t)}\gamma_{19} + FELH_{25}^{(t)}\gamma_{20} + FELH_{36}^{(t)}\gamma_{21}$$

$$KAPIG_9^{(t)} = FPN_{38}^{(t)}$$

(e) Sugar industry:

$$FELH_5^{(t)} = \gamma_{23}SPN_5^{(t)} + KAPIG_{10}^{(t)}$$

$$KAPIG_{10}^{(t)} = (nip - 0.01)KAPT_{10}^{(t)}$$

$$FPN_{39}^{(t)} = \gamma_{23}SPN_5^{(t)} + KAPIG_{10}^{(t)}$$

$$FELH_3^{(t)} = FELH_3^{(t)} + (1/\gamma_{24})\,KAP$$

$$KAPIG_{11}^{(t)} = \gamma_{23}SPN_5^{(t)}$$

(f) Canning industry:

$$FELH_{10}^{(t)} = SPN_{10}^{(t)} + HP_{10}^{(t)} - PTC_{10}^{(t)} - PTCG_{10}^{(t)} - TCS_{10}^{(t)} - PE_{10}^{(t)}$$

$$FPN_{40}^{(t)} = \gamma_{25}FELH_{10}^{(t)}$$

$$FELH_8^{(t)} = SPN_8^{(t)} + HP_8^{(t)} - PTC_8^{(t)} - PTCG_8^{(t)} - TCS_8^{(t)} - PE_8^{(t)}$$

$$FPN_{41}^{(t)} = \gamma_{26}FELH_8^{(t)}$$

$$KAPIG_{12}^{(t)} = FPN_{40}^{(t)} + FPN_{41}^{(t)}$$

(g) Wine industry:

$$FELH_{11}^{(t)} = SPN_{11}^{(t)} + (1 - \alpha_4)HP_{11}^{(t)} - PTC_{11}^{(t)} - PE_{11}^{(t)} - PTCG_{11}^{(t)}$$

$$FPN_{42}^{(t)} = \gamma_{27}FELH_{11}^{(t)}$$

$$KAPIG_{13}^{(t)} = FPN_{42}^{(t)}$$

(h) Other food processing:

$$FPN_{43}^{(t)} = (1 + \alpha_5)FPN_{43}^{(t-1)}$$

$$FELH_{22}^{(t)} = \gamma_{28}FPN_{43}^{(t)}$$

$$FELH_{33}^{(t)} = \gamma_{29}FPN_{43}^{(t)}$$

$$FELH_{39}^{(t)} = \gamma_{30}FPN_{43}^{(t)}$$

$$FELH_{42}^{(t)} = \gamma_{31} FPN_{43}^{(t)}$$

$$FELH_{9}^{(t)} = \gamma_{32} FPN_{43}^{(t)}$$

$$KAPIG_{14}^{(t)} = FPN_{43}^{(t)}$$

After the program of production, the unit production costs are calculated using commodity-specific rules as follows:

$$wf^{(t)} = (1 + t^{\mathrm{wa}}) w^{\mathrm{p}(t)}$$

$$OKT_{22}^{(t)} = (p_{1}^{\mathrm{pr}(t)} FELH_{1}^{(t)} + wf^{(t)} m_1 FELH_{1}^{(t)} + drp_1 RF_{1}^{(t)} + AKT_{1}^{(t)} - p_{23}^{\mathrm{pr}(t)} FPN_{23}^{(t)}) / FPN_{22}^{(t)}$$

$$OKT_{23}^{(t)} = p_{23}^{\mathrm{pr}(t)}$$

$$OKT_{24}^{(t)} = (p_{24}^{\mathrm{pr}(t)} FELH_{4}^{(t)} + drp_2 RF_{2}^{(t)} + wf^{(t)} m_2 FELH_{4}^{(t)} + AKT_{2}^{(t)} - p_{25}^{\mathrm{pr}(t)} FPN_{25}^{(t)}) / FPN_{24}^{(t)}$$

$$OKT_{25}^{(t)} = p_{25}^{\mathrm{pr}(t)}$$

$$OKT_{26}^{(t)} = \{(p_{12}^{\mathrm{pr}(t)} FELH_{12}^{(t)} + wf^{(t)} m_3 FELH_{12}^{(t)} + (FELH_{12}^{(t)} / KAPIG_{3}^{(t)}) (drp_3 RF_{3}^{(t)} + AKT_{3}^{(t)})\} / FPN_{26}^{(t)}$$

$$OKT_{27}^{(t)} = \{(p_{14}^{\mathrm{pr}(t)} + wf^{(t)} m_3) FELH_{14}^{(t)} + (FELH_{14}^{(t)} / KAPIG_{3}^{(t)}) (drp_3 RF_{3}^{(t)} + AKT_{3}^{(t)})\} / FPN_{27}^{(t)}$$

$$OKT_{28}^{(t)} = \{(p_{15}^{\mathrm{pr}(t)} + wf^{(t)} m_3) FELH_{15}^{(t)} + (FELH_{15}^{(t)} / KAPIG_{3}^{(t)}) (drp_3 RF_{3}^{(t)} + AKT_{3}^{(t)})\} / FPN_{28}^{(t)}$$

$$OKT_{29}^{(t)} = 0$$

$$OKT_{30}^{(t)} = \{p_{26}^{\mathrm{pr}(t)} FELH_{26}^{(t)} + p_{27}^{\mathrm{pr}(t)} \alpha_3 FELH_{27}^{(t)} + wf^{(t)} m_4 FPN_{30}^{(t)} + (FPN_{30}^{(t)} / KAPIG_{4}^{(t)}) (drp_4 RF_{4}^{(t)} + AKT_{4}^{(t)})\} / FPN_{30}^{(t)}$$

$$OKT_{31}^{(t)} = \{p_{27}^{\mathrm{pr}(t)} (1 - \alpha_3) FELH_{27}^{(t)} + wf^{(t)} m_4 FPN_{31}^{(t)} + (FPN_{31}^{(t)} / KAPIG_{4}^{(t)}) (drp_4 RF_{4}^{(t)} + AKT_{4}^{(t)})\} / FPN_{31}^{(t)}$$

$$OKT_{32}^{(t)} = [p_{17}^{\mathrm{pr}(t)} FELH_{17}^{(t)} + wf^{(t)} m_6 FELH_{17}^{(t)} + drp_6 RF_6^{(t)}$$
$$+ \{p_{32}^{\mathrm{pr}(t)} FPN_{32}^{(t)} / (p_{32}^{\mathrm{pr}(t)} FPN_{32}^{(t)} + p_{33}^{\mathrm{pr}(t)} FPN_{33}^{(t)})\} AKT_6^{(t)}] / FPN_{32}^{(t)}$$

$$OKT_{33}^{(t)} = [p_{18}^{\mathrm{pr}(t)} FELH_{18}^{(t)} + \{p_{33}^{\mathrm{pr}(t)} FPN_{33}^{(t)} / (p_{32}^{\mathrm{pr}(t)} FPN_{32}^{(t)}$$
$$+ p_{33}^{\mathrm{pr}(t)} FPN_{33}^{(t)})\} AKT_6^{(t)}] / FPN_{33}^{(t)}$$

$$OKT_{34}^{(t)} = (wf^{(t)} m_5 FELH_{29}^{(t)} + drp_5 RF_5^{(t)} + AKT_5^{(t)}) / FPN_{34}^{(t)}$$

$$X_1^{(t)} = p_{35}^{\mathrm{pr}(t)} FPN_{35}^{(t)} / (p_{35}^{\mathrm{pr}(t)} FPN_{35}^{(t)} + p_{36}^{\mathrm{pr}(t)} FPN_{36}^{(t)})$$

$$OKT_{35}^{(t)} = (p_{13}^{\mathrm{pr}(t)} FELH_{13}^{(t)} X_1 + wf^{(t)} m_7 FPN_{35}^{(t)} + drp_7 RF_7^{(t)} + AKT_7^{(t)}) / FPN_{35}^{(t)}$$

$$OKT_{36}^{(t)} = \{p_{13}^{\mathrm{pr}(t)} FELH_{13}^{(t)} (1 - X_1^{(t)}) + wf^{(t)} m_8 FPN_{36}^{(t)} + drp_8 RF_8^{(t)}$$
$$+ AKT_8^{(t)}\} / FPN_{36}^{(t)}$$

$$OKT_{37}^{(t)} = (p_{34}^{\mathrm{pr}(t)} FPN_{34}^{(t)} + p_{25}^{\mathrm{pr}(t)} FPN_{25}^{(t)} + p_{36}^{\mathrm{pr}(t)} FPN_{36}^{(t)}$$
$$+ p_{20}^{\mathrm{pr}(t)} FELH_{20}^{(t)}) / FPN_{37}^{(t)}$$

$$OKT_{38}^{(t)} = \{FELH_{37}^{(t)} p_{32}^{\mathrm{pr}(t)} + p_{23}^{\mathrm{pr}(t)} FELH_{23}^{(t)} + p_2^{\mathrm{pr}(t)} FELH_2^{(t)} + p_3^{\mathrm{pr}(t)} (FELH_3^{(t)}$$
$$- KAPT_{10}^{(t)} / \gamma_{24} + wf^{(t)} m_9 FPN_{38}^{(t)} + drp_9 RF_9^{(t)} + AKT_9^{(t)}\} / FPN_{38}^{(t)}$$

$$OKT_{39}^{(t)} = \{p_5^{\mathrm{pr}(t)} SPN_5^{(t)} + p_3^{\mathrm{pr}(t)} KAPT_{10}^{(t)} / \gamma_{24} + wf^{(t)} (m_{10} KAPT_{10}^{(t)}$$
$$+ m_{11} KAPIG_{11}^{(t)}) + drp_{10} RF_{10}^{(t)} + drp_{11} RF_{11}^{(t)} + AKT_{10}^{(t)}$$
$$+ AKT_{11}^{(t)}\} / FPN_{39}^{(t)}$$

$$OKT_{40}^{(t)} = \{p_{10}^{\mathrm{pr}(t)} FELH_{10}^{(t)} + wf^{(t)} m_{12} FPN_{40}^{(t)} + (FPN_{40}^{(t)} / KAPG_{12}^{(t)}) (drp_{12} RF_{12}^{(t)}$$
$$+ AKT_{12}^{(t)})\} / FPN_{40}^{(t)}$$

$$OKT_{41}^{(t)} = \{p_8^{\mathrm{pr}(t)} FELH_8^{(t)} + wf^{(t)} m_{12} FPN_{41}^{(t)}$$
$$+ (FPN_{41}^{(t)} / KAPKG_{12}^{(t)}) (drp_{12} RF_{12}^{(t)} + AKT_{12}^{(t)})\} / FPN_{41}^{(t)}$$

$$OKT_{42}^{(t)} = (p_{11}^{\mathrm{pr}(t)} FELH_{11}^{(t)} + wf^{(t)} m_{13} FPN_{42}^{(t)} + drp_{13} RF_{13}^{(t)} + AKT_{13}^{(t)}) / FPN_{42}^{(t)}$$

$$OKT_{43}^{(t)} = (p_{22}^{\mathrm{pr}(t)} FELH_{22}^{(t)} + p_{33}^{\mathrm{pr}(t)} FELH_{33}^{(t)} + p_{39}^{\mathrm{pr}(t)} FELH_{39}^{(t)} + p_{42}^{\mathrm{pr}(t)} FELH_{42}^{(t)}$$
$$+ p_9^{\mathrm{pr}(t)} FELH_9^{(t)} + drp_{14} RF_{14}^{(t)} + AKT_{14}^{(t)}) / FPN_{43}^{(t)}$$

Finally, the financial consequences of the given food processing activities are calculated.

(a) Labor requirements and expenses:

$$PLF^{(t)} = m_2 FELH_1^{(t)} + m_2 FELH_4^{(t)} + m_3(FELH_{12}^{(t)} + FELH_{14}^{(t)} + FELH_{15}^{(t)})$$

$$+ m_4(FPN_{30}^{(t)} + FPN_{31}^{(t)}) + m_5 FELH_{29}^{(t)} + m_6 FELH_{17}^{(t)} + m_7 FPN_{35}^{(t)}$$

$$+ m_8 FPN_{36}^{(t)} + m_9 FPN_{38}^{(t)} + m_{10} KAPT_{10}^{(t)} + m_{11} KAPIG_{11}^{(t)}$$

$$+ m_{12}(FPN_{40}^{(t)} + FPN_{41}^{(t)}) + m_{13} FPN_{42}^{(t)} + m_{14} FPN_{43}^{(t)}$$

$$w^{\mathrm{p}(t)} = w^{\mathrm{p}(t-1)}(1 + o^{(t)})$$

$$WEP^{(t)} = w^{\mathrm{p}(t)} PLF^{(t)}$$

$$LEP^{(t)} = (1 + t^{\mathrm{wa}}) WEP^{(t)}$$

(b) Other expenses:

$$DEP^{(t)} = \sum_{i=1}^{14} drp_i RF_i^{(t)}$$

$$MEPS^{(t)} = \sum_{i=1}^{21} p_i^{\mathrm{pr}(t)} FELH_i^{(t)}$$

$$MEPP^{(t)} = \sum_{i=22}^{43} p_i^{\mathrm{pr}(t)} FELH_i^{(t)}$$

$$MEPI^{(t)} = \sum_{k=1}^{14} AKT_i^{(t)}$$

$$MEP^{(t)} = MEPS^{(t)} + MEPP^{(t)} + MEPI^{(t)}$$

(c) Gross production value:

$$PAP^{(t)} = \sum_{i=22}^{43} p_i^{\mathrm{pr}(t)} FPN_i^{(t)}$$

(d) Net income from food processing:

$$INCP^{(t)} = PAP^{(t)} - \sum_{i=22}^{43} FPN_i^{(t)} OKT_i^{(t)}$$

2.3 Consumption and Trade Block

The Consumption and Trade Block of HAM-2 follows the general model outline completely. Parameters of the demand system were estimated on the basis of 25 years' data. The supply vector (Y) in HAM-2 is structured according to Table 18. The elements of the **Q** matrix in HAM-2 are shown in Table 19.

TABLE 18 Supply vector Y in HAM-2[a].

Stocks	Production	Household production	Used in processing	Inputs in household sector	Self consumption	Supply vector Y
$+S_1^{(t-1)}$	$+SPA_{91}$	$+HP_{01}$	$-FELH_{01}$	$-HD_8$		$= 1$
$+S_2^{(t-1)}$	$+SPA_{02}$		$-FELH_{02}$	$-HD_4$		$= 2$
$+S_3^{(t-1)}$	$+SPA_{03}$	$+HP_{03}$	$-FELH_{03}$	$-HD_5$ $-HBF_3$		$= 3$
$+S_4^{(t-1)}$	$+SPA_{04}$		$-FELH_{04}$			$= 4$
	$+SPA_{05}$		$-FELH_{05}$			$= 5$
	$+SPA_{06}$	$+HP_{06}$		$-HD_6$ $-HBF_6$		$= 6$
$+S_7^{(t-1)}$	$+SPA_{07}$	$+HP_{07}$		$-HD_9$	$-TCS_7$	$= 7$
$+S_8^{(t-1)}$	$+SPA_{08}$	$+HP_{08}$	$-FELH_{08}$		$-TCS_8$	$= 8$
$+S_9^{(t-1)}$	$+SPA_{09}$	$+HP_{09}$	$-FELH_{09}$		$-INFEL$	$= 9$
$+S_{10}^{(t-1)}$	$+SPA_{10}$	$+HP_{10}$	$-FELH_{10}$		$-TCS_{10}$	$= 10$
	$+SPA_{11}$	$+HP_{11}$	$-FELH_{11}$	$-HBF_{11}$	$-TCS_{11}$	$= 11$
	$+SPA_{12}$	$+HP_{12}$	$-FELH_{12}$			$= 12$
	$+SPA_{13}$	$+HP_{13}$	$-FELH_{13}$		$-TCS_{13}$	$= 13$
	$+SPA_{14}$	$+HP_{14}$	$-FELH_{14}$		$-TCS_{14}$	$= 14$
	$+SPA_{15}$	$+HP_{15}$	$-FELH_{15}$			$= 15$
	$+SPA_{16}$	$+HP_{16}$			$-GYFEL$	$= 16$
	$+SPA_{17}$	$+HP_{17}$	$-FELH_{17}$		$-TCS_{17}$	$= 17$
	$+SPA_{18}$	$+HP_{18}$	$-FELH_{18}$		$-TCS_{18}$	$= 18$
	$+SPA_{19}$	$+HP_{19}$			$-TCS_{19}$	$= 19$
$+S_{20}^{(t-1)}$	$+SPA_{20}$		$-FELH_{20}$			$= 20$
	$+SPA_{21}$				$-MTFEL$	$= 21$
$+S_{22}^{(t-1)}$	$+FPA_{22}$					$= 22$
$+S_{23}^{(t-1)}$	$+FPA_{23}$					$= 23$
$+S_{24}^{(t-1)}$	$+FPA_{24}$					$= 24$
	$+FPA_{25}$					$= 25$
$+S_{26}^{(t-1)}$	$+FPA_{26}$					$= 26$
$+S_{27}^{(t-1)}$	$+FPA_{27}$					$= 27$
$+S_{28}^{(t-1)}$	$+FPA_{28}$					$= 28$
	$+FPA_{29}$					$= 29$
$+S_{30}^{(t-1)}$	$+FPA_{30}$					$= 30$
$+S_{31}^{(t-1)}$	$+FPA_{31}$					$= 31$
$+S_{32}^{(t-1)}$	$+FPA_{32}$					$= 32$
$+S_{33}^{(t-1)}$	$+FPA_{33}$					$= 33$
	$+FPA_{34}$					$= 34$
$+S_{35}^{(t-1)}$	$+FPA_{35}$					$= 35$
$+S_{36}^{(t-1)}$	$+FPA_{36}$					$= 36$

TABLE 18 (*continued*)

Stocks	Production	Household production	Used in processing	Inputs in household sector	Self consumption	Supply vector Y
$+S_{37}^{(t-1)}$	$+FPA_{37}$					$=37$
$+S_{38}^{(t-1)}$	$+FPA_{38}$		$-KEVTI$	$-HD_7$		$=38$
$+S_{39}^{(t-1)}$	$+FPA_{39}$					$=39$
$+S_{40}^{(t-1)}$	$+FPA_{40}$					$=40$
$+S_{41}^{(t-1)}$	$+FPA_{41}$					$=41$
$+S_{42}^{(t-1)}$	$+FPA_{42}$	$+HP_{42}$			$-TCS_{42}$	$=42$
$+S_{43}^{(t-1)}$	$+FPA_{43}$					$=43$
$+S_{44}^{(t-1)}$						$=44$
$+S_{45}^{(t-1)}$						$=45$
$+S_{46}^{(t-1)}$	$+p_n$	$\alpha_{nn}^{n}p_n^{(t)}\frac{-MESI}{p_n^{pr}}$	$\frac{-MEPI}{p_n^{pr}}$	$\frac{-MEHI}{p_n^{pr}}$ $\frac{-INS}{p_n^{pr}}$	$\frac{-INP}{p_n^{pr}}$ $\frac{-INN}{p_n^{pr}}$	$=46$

[a]Symbols can be identified from Table 4 and the Appendix. All variables in Table 17 except stocks are related to period (t).

2.4 Economic Analysis of the Government and Updating of Parameters

The revision of government policy instruments in HAM-2 is modeled as explained in Part 1 and block updating also follows the general model outline.

3 VERIFICATION AND VALIDATION OF HAM-2

Through simulation models various real-life situations can be studied. The model must suit the purpose of the specific study and must also truly represent the aspect of reality in which we are interested. Accordingly, in developing HAM-2 great attention was paid both to the model's relation to reality and to the problem of the reliability of the results generated by the model.

The problems of agriculture, replete with random effects and biological correlations, can generally be represented only by complicated mathematical models and handled only by elaborate computer programs. It is not a simple task, therefore, to estimate how accurately a large-scale agricultural model such as HAM-2 reflects reality and how well the simulation system can be used with regard to the targets. Unfortunately there is almost no method that can be of definite help in this field.

The methodology of controlling and pretesting simulation models is still at a rudimentary stage. The philosophical interdependences and aspects of evaluating models cannot be regarded as fully or clearly defined and no widely accepted method of model evaluation has yet been established in international technical literature on simulation practice.

TABLE 19 Non-committed demands Q in HAM-2.

	Stocks			Investments				Community consumption			Private consumption		
	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7	λ_8	λ_9	λ_{10}	λ_{11}	λ_{12}	λ_{13}
1		*S*1											
2		*S*2											
3		*S*3											
4			*S*4										
5													
6													
7			*S*7							*PTCG*7			*TC*7
8			*S*8							*PTCG*8			*TC*8
9			*S*9										
10			*S*10							*PTCG*10			*TC*10
11										*PTCG*11			*TC*11
12													
13													
14													
15													
16													
17													
18													
19										*PTCG*19			*TC*19
20			*S*20										
21													
22			*S*22							*PTCG*22			*TC*22
23			*S*23										
24			*S*24							*PTCG*24			*TC*24
25													
26			*S*26							*PTCG*26			*TC*26
27			*S*27							*PTCG*27			*TC*27
28			*S*28										
29													
30			*S*30							*PTCG*30			*TC*30
31			*S*31							*PTCG*31			*TC*31

32			*S*32							*PTCG*32			*TC*32
33			*S*33							*PTCG*33			*TC*33
34													
35			*S*35							*PTCG*35			*TC*35
36			*S*36										
37			*S*37										
38			*S*38										
39		*S*39								*PTCG*39			*TC*39
40			*S*40							*PTCG*40			*TC*40
41			*S*41							*PTCG*41			*TC*41
42		*S*42							*PTCG*42			*TC*42	
43			*S*43							*PTCG*43			*TC*43
44		*S*44							*PTCG*44			*TC*44	
45		*S*45							*PTCG*45			*TC*45	
46	*S*46			*PDGINA*	*GINN*	*PGINSA*	*PGINSP*	*PTCG*46			*TC*46		

However, most works dealing more thoroughly with simulation emphasize the advantages of performing a two-way analysis before operating the model. The first stage is the verification of the model, that is, the confrontation of the model with reality to determine whether the model truly represents reality. The second stage is the validation of the model, that is, the necessary evaluation of the model in respect of a specific analysis, rather than with regard to reality, to study to what extent the model satisfies certain objectives of research or investigation.

The model's relation to reality can be expressed by the relation of the characteristics of the system studied determined by the computer on the basis of the model and the characteristics of the real system. Thus the proof of reliability is the total or partial conformity of certain values of the dependent variables with the results of the empirical studies concerning the phenomena symbolized by the former. On this basis one can decide whether the model properly represents the situation to be described. In principle, therefore, the model's relation to reality can be easily defined, but to prove this in specific cases is more difficult. This is due not only to the lack of suitable methods for this purpose but frequently also to the missing bases of comparison. There are almost no empirical data about how a certain part of the modeled systems operate. There are also cases where the system studied (some plan interrelations, for instance) does not even exist in reality and therefore no factual data concerning its functioning are available either.

Verification is relatively simpler if the model describes an existing system and the results of the model can be compared with factual data from real-life situations. The various methods of statistical analysis may play an important part in evaluating simulation methods. If model results are given in the form of time series, the following tests are suggested:

- statistical tests, indifferent to distribution, to check whether actual and simulated time series tend in the same direction;
- regression of simulated time series with the actual time series;
- factor analysis of the two time series to check whether the levels of factors differ considerably.

When results are given in the form of averages, ratios or probability distributions, the usual statistical methods of verifying the hypotheses are applied. None of these tests can generally be done during the course of the simulation study. The executors of the simulation therefore have to choose those indicators through which they intend to verify the relation of the simulation model to reality.

T.H. Naylor's so-called multiple-stage model verification process is perhaps the best-known procedure in the technical literature on simulation. The essentials of this three-phase method are as follows:

- selection of assumptions and hypotheses of basic importance from the point of view of describing the system studied;
- the logical testing of the basic assumptions;
- the empirical study of the model's behavior.

Naylor's method comprises an evaluation of a logical type. Such an evaluation is necessary because normally the basic hypotheses of the models cannot be checked in any other way.

In the further phases of the checking process, Naylor starts from the assumption that the behavior of the simulation model as a whole may be forecast on the basis of only some of the variables. If values are attributed to some of the variables, the results expected on the basis of the model, i.e. the features of the operation of the simulated system, can be obtained. These features can then be compared with the data for the operation of the real system. For comparison the aforementioned statistical methods may be applied.

If empirical data for the operation of the modeled system is lacking, an evaluation can be performed only on a subjective basis. Subjective judgment cannot be excluded even if we can carry our exact tests. The level and the exactness of the approach considered as the proof of the correspondence to reality undoubtedly also have a bearing on the problem, but primarily results depend on the objectives of the study and to a large extent on the subjective judgment of the person in charge of checking. No absolute standards or levels can be set to estimate the model's relation to reality. Lacking such objective standards, we must accept the results of various confidence limits in the simulation practice. It is important to stress, therefore, that the realization of the simulation process overwhelmingly depends on the sense of scientific responsibility and the conscience of the executors.

Depending on the nature of the problem, model verification and testing may be covered in either a simpler or a more complicated way. In the case where the system exists in real life and can be described by a linear–deterministic model, verification can generally rely on objective bases and statistical methods. However, for the simulation of more complicated biological and economic systems, logical testing of the main postulates of the model should not be neglected either. The applicability of such models can be considered as confirmed only if both logical and exact tests show positive results.

Because HAM-2 describes a rather complex and complicated system, several controls were made in the process of developing the model.

As part of the model construction, the correspondence to reality of the mathematical model was studied first. Having constructed the model, the positive results of control evaluations permitted procedure to the next stages and ensured that possible errors in the early stage were avoided. If the model is regarded problematically at some point or points, it is necessary to return to the model construction, or eventually to the analysis of the system itself, and to repeat and to check on the stages of model construction mentioned previously.

It should be borne in mind when evaluating the model's mathematical structure that the use of mathematical models always implies certain abstractions from the particulars of reality and that objective conditions often make the precise, exact modeling of certain interdependences impossible from the outset. We considered the following to be characteristic features of a satisfactory model:

- each component of the system studied is represented by a corresponding variable or variables;
- the parameters are reliable;
- concerning logic and mathematics, the interdependences are formulated exactly and correctly;
- the model is easily explicable and applicable;
- the structure of the model is determined by the objectives of the study;
- the model can be easily adapted to new postulates and relatively easily developed.

In the case of HAM-2, the satisfaction of these requirements has been confirmed logically, empirically and by subjective judgment. Verification on a logical basis included comparison with the field studied, the examination of the model's structure and the thorough, logical analysis of the interdependences of the model. Empirical investigations included simpler, manual calculations to show what values the dependent variables may take and how these values relate to empirical results for the phenomena represented by them. The evaluation of certain model parts was performed on a subjective basis. While it is generally not good for subjective judgment to play too great a part, in some situations this is the only method available and there is no other choice but to rely on general experience and knowledge.

In relation to the structure of HAM-2, a so-called sensitivity analysis was also performed. The sensitivity analysis was connected with parameters, coefficients and other factors of the model whose values had been fixed in advance and thus do not change during the operation of the model. Of the components of the model mentioned. those primarily selected were those which were in some respect uncertain or less exact, or whose reliability was doubtful.

In the course of the sensitivity analysis of HAM-2 we changed the values of the selected parameters that were considered unreliable, leaving the rest of the model unaltered. In this way we were able to estimate how and to what degree this change influenced the operation of the model, and in what way the characteristics of the simulated system changed. The main purpose of the sensitivity analysis was to show whether alteration of the uncertain parameters influenced the model's correspondence to reality and, if it did, to what extent. In general a model is in sensitive relation to one or more of its parameters if their values considerably influence the picture drawn of the system studied by the model. Sensitivity means therefore that if we modify the values of unreliable parameters the model loses its suitability for simulating the system studied. To gain positive results from the sensitivity analysis, it is necessary to return to an earlier phase of the model building and to reconsider the interrelations of the studied system as described by the model. At the same time, additional data has to be collected to carry on the survey further in order to define the parameters in question more exactly and thoroughly. A simulation will be really reliable only if the results of a sensitivity analysis are satisfactory. In the case of HAM-2, the sensitivity analysis was mainly related to parameters of the production block and parameters in the government economic analysis submodel.

In addition to analyzing the relationship between the model and reality, we tested whether HAM-2 was correct from the point of view of computer programming. Several computer runs of the model were made to answer these questions. These test runs were aimed at revealing any errors and shortcomings in the computer program. In this work we applied the following methods:

- the model was run simulating a shorter time period (only one year) and the results were compared with those of manual calculations;
- the more complicated independent routines were separately run and tested;
- simple control situations were constructed to test the most frequently occurring circumstances.

The checking of the model, especially the sensitivity analysis and the program testing, involved a great deal of calculation and time. We have learnt from HAM-2 that the verification and validation of the model play a very important part in the simulation process. We also learnt through experience that repeated checking during the course of simulation is very necessary since the probability of making errors multiplies itself. Errors can occur during the construction of the mathematical model, during computer programming, in data collection, in operating the model and in evaluating the information yielded by the model.

The first control point comes after building the mathematical model. Having settled all questions related to computer processing, a complex testing of the whole simulation system should be made. Either these tests confirm the answers to the problems of the model, or it is necessary to return to the model and eliminate the errors by carrying out certain alterations and repeating certain phases of the model construction. On the whole, the utility of the information can be the final standard of the success of the simulation. There may be cases when certain problems with the model appear only after the simulation is completed. Nothing else can then be done but to recommence model construction by the repeated study of the system and to try to find a solution that might produce really valuable information satisfying the objectives of the study. Figure 33 shows the role of testing in the development of HAM-2.

4 EXPERIMENTS IN THE USE OF HAM-2

The computer program of HAM-2 was developed in Hungary at the computer center of the Hungarian National Planning Bureau under the leadership of Laszlo Zeold. In the programming work the computer program of HAM-1 was used as a starting point. At present one program version exists, allowing us to do runs on the Hungarian Planning Bureau's ICL-System 4/70 computer.

At the end of the computation various types of output can be printed out. At present the output system of HAM-2 consists of the following two major elements.

(1) Annual Results, which provide the analysis of time periods, containing very detailed results on each simulated year and on each module of the model, including the updated model coefficients.

(2) A Summary of Results which covers time series of the most important indicators, making possible the global analysis of the various runs.

The Summary of Results is the most useful type of output, and in most cases the information needs on the individual runs can be satisfied on the basis of it. Of course, the more detailed analysis or debugging can only be done using the Annual Results. The Summary of Results is structured according to eight tables as described in the following.

(1) Dynamics of production, trade, and prices: planned and actual production, export and import of individual commodities in physical units and unit production costs, and domestic producer, consumer and world market prices also according to commodities and simulated years.

(2) General indicators of development: general indicators of production, foreign trade, investment, income development on current and fixed prices for the entire simulated period and indexes of the development in comparison with major plan targets.

(3) Cropping structure and yields: share of individual crops in total plowland and their projected unit outputs in physical terms.

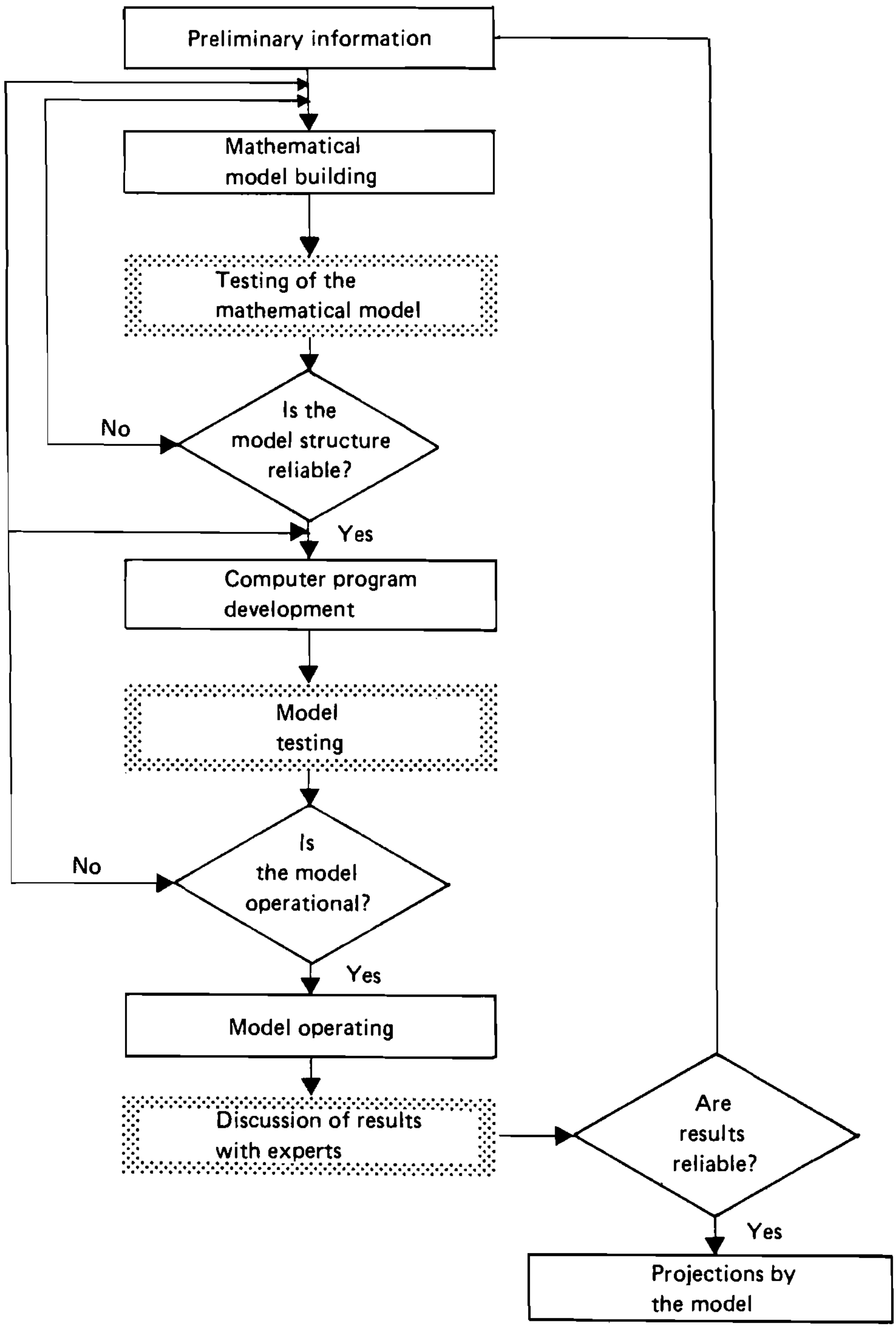


FIGURE 33 Structure of verification and validation in developing HAM-2.

(4) Fixed Assets: the development of fixed assets of agriculture and food processing by major types, in physical units.

(5) Financing of investments: financial accounts for investment, for the producing sector and for the whole economy, according to simulated years.

(6) Resources: summary of major production resources including labor and land.

(7) Foreign trade: balance of payments for food and agriculture and the whole economy, total exports and imports according to dollar and ruble market values.

(8) Dynamics of consumption: the desired and actual per capita consumption by commodities in physical units.

(9) Policy instruments: tax rate and centralized part of amortization, annual growth of unit wages.

Numerous runs of HAM-2 have been done so far, representing two types of investigations, namely:

- testing the operation of the whole system, and investigating the model's relation to reality;
- investigation related to the elaboration of the five-year plan of Hungarian food and agriculture for the period 1981–85.

A large number of runs belonged to the first of these two types, some of them simply serving debugging purposes. In other cases the sensitivities of the crucial parameters were investigated. Finally, several runs were required to test our assumptions on various decision-making procedures. These runs led us to the so-called basic variant of HAM-2, which can be considered as the appropriate description of the present Hungarian food and agriculture system, obviously on the aggregation level and accepting the assumptions of the model.

The use of HAM-2 for actual planning purposes began in mid-1979 and the work is far from finished. After first testing the model, HAM-2 was used to aid decision making on further development of domestic agricultural price systems as well as pricing mechanisms. Runs of HAM-2 have been made:

- with various assumptions about the relative prices of major agricultural commodities;
- with modifications to the pricing mechanism built into the model according to the major alternatives considered as future possibilities by the National Planning Bureau.

As further stages in the use of HAM-2, the following were investigated:

- strategies for the further development of the food export structure;
- the efficiency of increasing food exports in return for oil;
- the major alternatives for investment in food and agriculture (agriculture versus food processing);
- the feasibility of major growth targets in food and agriculture;
- the alternatives for technological development.

HAM-2 will also be used to project the overall indicators of agricultural development and export–import possibilities within the framework of a research project of the

Hungarian Academy of Sciences on the biological potential and ecological limits of Hungarian agriculture. On the basis of the results of this project, the Production block of HAM-2 might also be further refined.

5 SOME PERSPECTIVES ON HUNGARIAN AGRICULTURE AS PROJECTED BY HAM-2

During 1979 40 or so runs of HAM-2 were executed to answer questions related to the mid-range development of Hungarian agriculture. The detailed discussion of the results exceeds the scope of this study; only the major conclusions of the investigation will be summarized here.

One of the most important tasks during the calculations was to project the growth of the Hungarian national economy and agriculture. The basic trends of development in Hungarian agriculture are shown in Fig. 34. The results show that in comparison with the

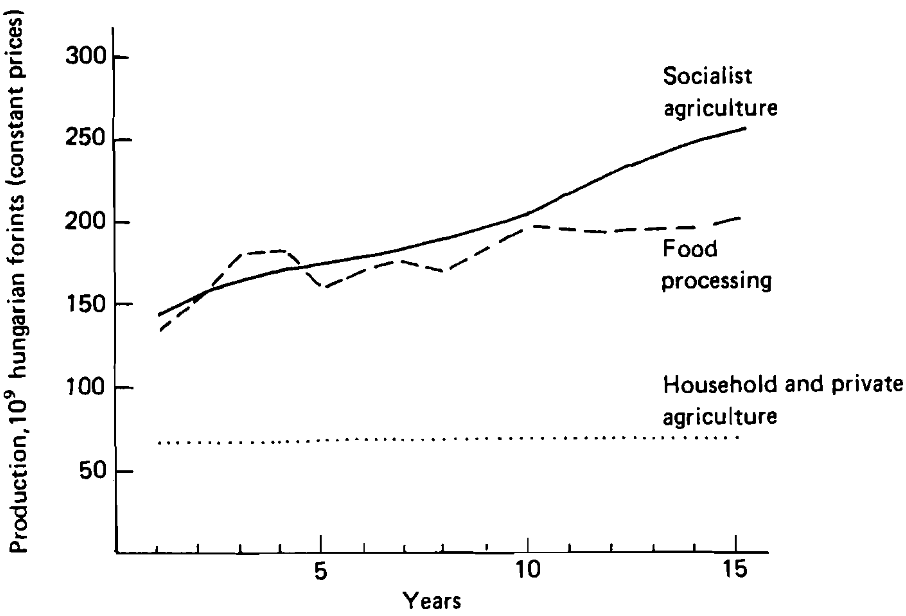


FIGURE 34 Basic trends in the development of Hungarian food and agriculture as projected by HAM-2.

1960s the annual rate of growth will increase slightly, both on the national level and in food and agriculture. Within the conditions expressed by the model, it is most likely that the average annual rate of growth of the gross national product will be about 3%. The annual growth will probably decrease toward the second five-year period within the time horizon modeled. Later it will increase again but it will probably not reach the level of the first five-year period. Food and agriculture grows in parallel with the growth of 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.

The various conditions impact to various extents upon growth. As far as external conditions are concerned, exogenously given scenarios have been investigated to aid decision making. Several assumptions on international prices and world market conditions were tested. The results indicate the following:

- that stable international market conditions help the achievement of growth targets;
- that the reactions of the Hungarian economy, including food and agriculture, to world market changes is slow;
- that changes in food export quotas do not significantly influence the overall growth figures.

Relations between government policy instruments, the economic management system and growth were also studied. Some of the most important conclusions in this respect are as follows.

- The transfer of international market changes to producers is not efficient enough. Producers have no direct contact with the world market and their actions might therefore lead to undesired results.
- As had been expected, exchange rates proved to be inefficient instruments for controlling overall growth.
- Government policy objectives for the growth of private consumption impacts heavily on the overall economic growth. The overall economic growth is most favorable assuming only a 2% annual growth in consumption. An annual growth in consumption of more than 3.5% leads to a very substantial slowdown in overall economic development. However, too slow an increase in consumption also has negative effects on production. The most realistic target for the annual growth of private consumption for the forthcoming 15 years therefore seems to be 2.5–3.0%.
- The impacts of various government pricing policies were also investigated. Results have confirmed our expectations: prices and price policy are the most efficient tool in the hands of the government to control producers' behavior within the framework of conditions expressed by HAM.

The desired relation of consumption to investment was also 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 2.5–3.0% seems the most desirable. According to the results of various runs, the given stage of the economy very seriously limits the possibilities for increased consumption. Obviously an increased 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. Otherwise the higher growth in consumption decreases investment and overall economic growth falls below the desired level. An almost general conclusion of our calculations is that a slowly increasing rate of investment of national income would be the most desirable for the future; the growth of investment should therefore be higher than the growth of consumption.

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

The share of food and agriculture in total accumulation varies to a great extent in the various 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, government subsidies are the major financial source for development. It is not surprising that most of our runs reflect a relatively acceptable level of incomes in agriculture. In food processing, partly owing to the age of the present production facilities, firms are unable to accumulate enough money to finance the desired investments at the domestic price level projected by HAM-2.

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

- the export potential of Hungarian agriculture has so far not been fully utilized – the positive balance of food and agricultural foreign trade can be significantly increased;
- the quantity of exports might 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, however, they do not indicate the need for any substantial change in the present production structure. However, they do indicate that the following changes should be considered:

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

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APPENDIX List of Symbols in General Model Outline and in HAM-2

Symbol	Quantity	Where determined
A		
a	Desired growth rate of GNP at constant prices	Exogenous
$a_{kij}^{s(t)}$	Unit input coefficient in socialist agriculture	UD-4
$ADMS^{(t)}$	Number of administrative staff in agriculture	P-2
$af^{(t)}$	Actual growth rate of GNP at constant prices	GM-A-1
$AGF^{(t)}$	Total material expenses in million forints	CT-1
ak', ak''	Lower and upper bounds of desired growth of GNP	Exogenous
ak_1	Minimum value of ak'	Exogenous
ak_2	Maximum value of ak''	Exogenous
AKT_k	Overhead expenses related to kth production's facility of food processing in million forints	UD-4
APH_i	Unit output of the ith commodity in household and private sector	Exogenous
ASP^t	New saving of populations in million forints	CT-1
ati_k	Time requirement of kth investment ($k = 1,2,\ldots,$ 26)	Exogenous

B

b	Desired growth rate of GNP in food and agriculture at constant prices	Exogenous
$BARMI_i^{(t)}$	Total direct expenses in production of commodity i	P-2
$b_{ij}^{s(t)}$	Labor input coefficient in socialist agriculture	UD-4
bf_1^t	Actual growth rate of GNP in food and agriculture	GM-A-1
bf_2^t	Growth rate of gross production in the rest of the economy at constant prices	GM-A-1
bk', bk''	Lower and upper bound of desired growth rate of GNP in food and agriculture	Exogenous
BN^t	Bonus paid by the rest of the economy in million forints	CT-1
BP^t	Bonus paid by food processing in million forints	CT-1
BS^t	Bonus paid by socialist agriculture in million forints	CT-1

C

c^t	Planned decrease of allowed deficit of price balance of payments	Exogenous
$c1_{1-46}$, $c2_{1-46}$	Parameters of demand system	Exogenous
$c3_{1-19}$, $c4_{1-19}$	Parameters in supply function of household and private sector	Exogenous
CON^t	Total value of goods bought by the population at constant price	CT-4
$CONP^t$	Total value of goods bought by the population at producer price	CT-4
$CONS^t$	Self-consumption of products of household and private farms at producer price	P-1
CPE^t	Per capita endowment of consumers	CT-1

D

$dc^{n(t)}$	Centralized part of amortization in the rest of the economy	GM-A-1
$dc^{p(t)}$	Centralized part of amortization in food processing	GM-A-1
$dc^{s(t)}$	Centralized part of amortization in socialist agriculture	GM-A-1
ddn	Rate of renewal of facilities in the rest of the economy	Exogenous
ddp_{1-14}	Rate of renewal of facilities in food processing	Exogenous
dds_{1-12}	Rate of renewal of facilities in socialist agriculture	Exogenous
DEF^t	Total loss in producing sectors	CT-1
DEN^t	Total amortization in rest of the economy	CT-1

DEP^t	Total amortization in food processing	CT-1
DES^t	Total amortization in socialist agriculture	CT-1
$DESPN^t$	Total amortization in the rest of the economy	CT-1
$devcp_i$	Allowed deviation of consumer price from scale of producer price as percentage of producer price	Exogenous
$devla$	Steps in changing λ parameters	Exogenous
$devpp_i$	Scale of allowed deviation of actual production from target as a percentage of target	Exogenous
$devpp_i$	Scale of allowed deviation of producer price from production expenses as a percentage of expenses	Exogenous
$devtc_i$	Scale of allowed deviation from desired per capita consumption of commodity *i* in percentage of actual figure	Exogenous
$DGNP^t$	Planned value of GNP	GM-P-12
$DGNPA^t$	Planned value of GNP from food and agriculture	GM-P-12
$DPBA^t$	Planned balance of payments from food and agriculture in million forints	GM-P-12
drn	Rate of amortization in the rest of the economy	Exogenous
drp_{1-14}	Rate of amortization of production facilities in food processing	Exogenous
drs_{1-12}	Rate of amortization of production facilities in socialist agriculture	Exogenous
ds	US dollar/Hungarian forint exchange rate	Exogenous

E

e	Desired growth rate of net national product	Exogenous
$ef^{(t)}$	Actual growth rate of net national product at current prices	CT-1
$ep^{g(t)}$	Planned growth rate of community consumption	Exogenous
es^g	Growth rate of government social expenditures	Exogenous
e_a, e_m, e_n	Coefficients used to forecast general management and overhead expenses	Exogenous
E_i^t	Export of commodity *i*	CT-3
EI_i^t	Balance of export–import of commodity *i*	CT-3

F

f^t	Desired share of consumption in national income	GM-A-1
$FELH_i^t$	Quantity of commodity *i* used for processing	P-4

ff^t	Actual share of consumption in national income	CT-4
FP_i^t	Scale of branch *i* in food processing	P-4
FPA_i^t	Net production of commodity *i* in food processing	P-4
FPN_i^t	Production of *i*th commodity in food processing	P-4

G

g^t	Planned share of food and agriculture in total investment	GM-A-1
GCS^t	Government subsidy to consumer prices	CT-4
GD^t	Centralized amortization	CT-1
GE^t	Total government expenditure	CT-4
GES^t	Total export subsidy	CT-4
gf^t	Actual share of food and agriculture in total investment	CT-4
GI^t	Total income of government	CT-4
$GINA^t$	Direct government investment in food and agriculture	CT-3
$GINN^t$	Direct government investment in the rest of the economy	CT-3
$GINS^t$	Government subsidy to investment in food and agriculture	CT-3
GIS^t	Government import subsidy	CT-3
$GISX^t$	Balance of government budget	CT-4
GNP^t	Gross national product	CT-4
$GNPA^t$	Gross national product in food and agriculture	CT-4
GP^t	Government price subsidies	CT-4
GPE^t	Community consumption at producer prices	CT-1
GSP^t	Government social expenditures	CT-1
GT^t	Total tax returns of government	CT-1
$GTRP^t$	Tariff receipts of government	CT-4
$GYFEL^t$	Wool processed in the rest of the economy	P-3

H

h	Desired share of investment in socialist agriculture in investment in the whole food and agricultural sector	Exogenous
HAP^t	Gross production value of household and private agriculture	P-1
HBF_3	Intermediate consumption of corn in household and private agriculture	P-1

HBF_6	Intermediate consumption of green feeds in household and private agriculture	P-1
HBF_{11}	Intermediate consumption of grapes in household and private agriculture	P-1
hci	Growth rate of self-consumption of commodities produced by household and private agriculture	Exogenous
HD_k^t	Demand of household and private agriculture for *k*th production facility of socialist agriculture	P-1
$HDES^t$	Amortization of resources of socialist agriculture used in the household and private sector	P-1
HMI^t	Industrial inputs related to production facilities of the rest of the economy used in household and private sector	P-1
HP_i^t	Production of commodity *i* in household and private sector	P-1
hpri	Projected growth of production in the household and private sector	Exogenous
$HWES^t$	Labor expenses related to production facilities of socialist agriculture used in the household and private sector	P-1

I

i^t	Desired growth rate of total consumption	GM-A-1
I_i^t	Import of the commodity *i*	CT-3
$IFEAN^t$	Investment fund of enterprises in the rest of the economy	CT-1
$IFEP^t$	Investment fund of firms in food processing	CT-1
$IFES^t$	Investment fund of farms in socialist agriculture	CT-1
IKT_1	Unit costs of tractor type I usage	Exogenous
IKT_2	Unit costs of tractor type II usage	Exogenous
IKT_3	Unit cost of additional equipment use	Exogenous
$IKTO^t$	Total expenses of resources of socialist agriculture used in household and private agriculture	P-1
IRA_1^t	Expenses of fertilizer usage in socialist agriculture	P-2
IRA_2^t	Total expenses on pesticides in socialist agriculture	P-2
IRA_3^t	Value of products and services of the rest of the economy used in socialist agriculture	P-2
$INCN^t$	Net income realized in the rest of the economy	CT-1

$INCP^t$	Net income realized in food processing	CT-1
$INCPO^t$	Net income of population	CT-1
$INCS^t$	Net income realized in socialist agriculture	CT-1
$INFEL^t$	Products of other plant production used in the rest of the economy	CT-1
INH^t	Income of population from household and private agriculture	P-1
INN^t	Investments financed by firms' own resources in the rest of the economy	P-6
INP^t	Investments financed by firms' own resources in food processing	P-6
INS^t	Investments financed by farms' own resources in socialist agriculture	P-6
INV_k^t	Amount of enterprise level investments in kth production facility	GM-P-4
$INVI_k$	Vector including the codes of investment possibilities for a given year	GM-P-4
$INVU_k$	Scale of investment in production facility k	Exogenous
ITC_i^t	Desired per capita consumption of commodity i	GM-A-2
$itci_i$	Rate of change of desired per capita consumption of commodity i	Exogenous

K

KA^t	Permitted balance of payments deficit	GM-P-1-2
$KAP_k^{(t)}$	Availability of production facility k in socialist agriculture	P-2
$KAPIG_k^t$	Need for production facility k in food processing	P-4
$KAPT_k$	Availability of kth production facility in food processing	P-4
$KEVAB^t$	Protein requirement of socialist agriculture	P-2
$KEVFE^t$	Protein feed requirement of socialist agriculture	P-2
$KEVTI^t$	Feed mix requirement of socialist agriculture	P-2

L

la_i	Change of ith element of vector λ\	Exogenous
LAF^t	Labor force in agriculture and food processing	P-2-4
LEN^t	Wages and related tax in the rest of the economy	P-5
LEP^t	Wages and related tax in food processing	P-4

LES^t	Wages and related tax in socialist agriculture	P-2
lh	Annual rate of change of land resource in household and private agriculture	Exogenous
$LS_1^{(t)}$	Plowland of socialist agriculture	P-2
$LS_2^{(t)}$	Pastures and meadows in socialist agriculture	P-2
LSH^t	Land availability for household and private agriculture	P-1
lsi_1	Annual rate of change of plowland belonging to socialist agriculture	Exogenous
lsi_2	Rate of change of available pastures and meadows	Exogenous
LTS^t	Land tax paid by socialist agriculture	P-2
M		
m_k	Unit labor input coefficient related to kth production facility	Exogenous
MEH^t	Expenses of household and private agriculture related to usage of production facility	P-1
$MEHI^t$	Fertilizer and pesticides expenses in household and private agriculture	P-1
MEN^t	Intermediate inputs of nth commodity in the rest of the economy	P-5
MEP^t	Total material expenses in food processing	P-4
$MEPI^t$	Value of the nth commodity used in food processing	P-4
$MEPP^t$	Intermediate inputs of food processing	P-4
$MEPS^t$	Value of raw materials used in agriculture and in food processing	P-4
MES^t	Total material expenses in socialist agriculture	P-2
$MESI^t$	Value of nth commodity used in socialist agriculture	P-2
$MESP^t$	Value of feed mix used in socialist agriaculture	P-2
$MESS^t$	Value of agricultural materials used in socialist agriculture	P-2
N		
NLF^t	Labor force of the rest of the economy	P-5
NNP^t	Net national product	CT-4
O		
o^t	Rate of change in wages	GM-P-1-2
OKT_i^t	Production expenses of one unit ith commodity	P-3, P-5

P

$p_i^{c(t)}$	Consumer price of *i*th commodity	GM-A-3
$p_i^{pr(t)}$	Producer price of *i*th commodity	GM-A-2
$p_i^{w(t)}$	International price of *i*th commodity	Exogenous
P_n^t	Gross production in the rest of the economy	P-5
PAF^t	Planned investment fund for the whole national economy	GM-P-1-2
$PAFA^t$	Planned investment fund in agriculture and food processing	GM-P-1-2
$PAFN^t$	Planned investment fund in the rest of the economy	GM-P-1-2, CT-3
PAP^t	Gross production value of food processing	P-4
PBA^t	Balance of foreign trade related to food and agriculture	CT-4
pci	Consumer price index	GM-A-1-2
PCF^t	Planned consumption fund	GM-P-1-2
$PCPE^t$	Planned value of per capita consumption	GM-P-1-2
$PCTOT^t$	Planned consumption at producers' price	GM-P-1-2
$PDGINA^t$	Planned direct government investment in socialist agriculture	GM-P-1-2
PE_i^t	Planned export of commodity i	GM-P-3
$PGINS^t$	Planned investments of firms in food and agriculture	GM-P-1-2
$PGINSA^t$	Planned government subsidy to agricultural investments	GM-P-4, CT-3
$PGINSP^t$	Planned government subsidy to investments in food processing	GM-P-4, CT-3
$PGPE^t$	Planned value of community consumption	GM-P-1-2
PI_i^t	Planned imports of commodity i	GM-P-3
$PJOV^t$	Planned value of income of population used for buying goods	GM-P-1-2
pkp_k	Unit price of kth production facility of food processing	UD-4
pks_k	Unit price of kth production facility in socialist agriculture	UD-4
PLF^t	Labor force in food processing	P-4
$PMUTR^t$	Unit price of fertilizer	UD-4
$PNNP^t$	Planned net national product	GM-P-1-2
POT_k^t	Value of replacement from production facility k	P-6
PP_i^t	Planned scale of production	GM-P-3
PPN_i^t	Planned production of commodity i	GM-P-3

$PSLF^{(t)}$	Planned labor force of socialist agriculture	P-2
PTC_i^t	Planned quantity of commodity *i* bought by population	GM-P-3
$PTCG_i^t$	Planned community consumption of commodity *i*	GM-P-1-2, CT-3
$PTPE^t$	Planned endowment of population	GM-P-1-2
PYO^t	Planned balance of export and import	GM-P-1-2
Q		
Q	Matrix on noncommitted demands	CT-3
R		
r_1^t	Share of food and agriculture in the gross national product	GM-A-1
r_2^t	Share of the rest of the economy in the gross national product	GM-A-1
RF_k^t	Value of capital stock in food processing	UD-2
RN^t	Capital stock in the rest of the economy	UD-2
RS_k^t	Capital stock in agriculture	UD-2
S		
S_i^t	Stock of commodity *i*	CT-4
SAG^t	Accumulated savings of population	CT-4
SAP^t	Gross production value of socialist agriculture	P-2
SDN^t	Value of the increase in stocks in the rest of the economy	CT-4
SDP^t	Value of the increase in stocks in food processing	CT-4
SDS^t	Value of increase of stocks in socialist agriculture	CT-4
$SEXP^t$	Exports at producers' prices	CT-4
SGM^t	Overhead expenses in socialist agriculture	P-2
$SGMA^t$	Other fixed asset requirements of management activities in socialist agriculture	P-2
$SGMM^t$	Labor expenses within overhead expenses	P-2
$SGMN^t$	Use of *n*th commodity as a fraction of overhead expenses	P-2
$SIMP^t$	Import at producer price	CT-4
$SKAPIG_k^t$	Needs for *k*th production facility in socialist agriculture	P-2
$SKAPT_k^t$	Capacity of *k*th production facility in socialist agriculture	UD-2
SLF^t	Labor force of socialist agriculture	P-2
SP_i^t	Scale of production branch *i* in socialist agriculture	P-2

SPA_i^t	Output of commodity *i* from socialist agriculture	P-2
SPN_i^t	Total production of commodity *i* in socialist agriculture	P-3
$SPRI_k^t$	Shadow price of production facility *k*	GM-P-3, P-2
$SPT_{i,j}^t$	Scale of production of commodity *i* using technology *j*	P-2

T

$t^{\text{in},\text{h}(t)}$	Income tax rate in household farms	GM-A-1
$t^{\text{in},\text{n}(t)}$	Income tax rate in the rest of the economy	GM-A-1
$t^{\text{in},\text{p}(t)}$	Income tax rate in food processing	GM-A-1
$t^{\text{in},\text{po}(t)}$	Income tax rate of the population	GM-A-1
$t^{\text{in},\text{s}(t)}$	Income tax rate of socialist agriculture	GM-A-1
$t^{\text{l}(t)}$	Land tax rate in period *t*	GM-A-1
$t^{\text{wa}(t)}$	Wage tax rate	GM-A-1
TC_i^t	Total consumption of commodity *i* from personal income of population	CT-2
TCS_i^t	Consumption of commodity *i* in household farms	P-1
TES^t	Total production expenses of socialist agriculture	P-2
TIN^t	Total accumulation	CT-4
$TINP^t$	Investment in food processing	CT-4
$TINS^t$	Investment in agriculture	CT-4
tp^t	Total population	UD-1
TPE^t	Income of population used for consumption	CT-1
tpi	Annual growth rate of total population	Exogenous
$TRCP^t$	Government receipts from consumer prices	CT-5
$TREP^t$	Government receipts from exports	CT-5
$TRIP^t$	Government receipts from imports	CT-5
TXH^t	Income tax paid by household farms	P-1
TXN^t	Tax paid by the rest of the economy	P-5
TXP^t	Tax paid by food processing	CT-1
$TXPO^t$	Tax paid by population	CT-1
TXS^t	Tax paid by socialist agriculture	CT-1
TWH^t	Total hours of work used in farming households	UD-1
$TWHA^t$	Hours of work used in household animal husbandry	P-1
$TWHV^t$	Hours of work used in household plant production	P-1

U

uip	Level of utilization of production facilities in food processing above which new investment is desirable	Exogenous
upp	Level of utilization of resources in food processing above which replacement of obsolescent facilities is desirable	Exogenous
ups	Level of utilization of production facilities in socialist agriculture above which replacement of obsolescent facilities is desirable	Exogenous

V

v^{n}	Share of rewards in the net income of the rest of the economy	Exogenous
v^{p}	Share of rewards in the net income of food processing	Exogenous
v^{s}	Share of rewards in the net income of socialist agriculture	Exogenous

W

$w^{n(t)}$	Per capita wages in the rest of the economy	P-5
$w^{p(t)}$	Per capita wages in food processing	P-4
$w^{s(t)}$	Per capita wages in socialist agriculture	P-2
WEN^{t}	Total wages in the rest of the economy	P-5
WEP^{t}	Total wages in food processing	P-4
WES^{t}	Total wages in socialist agriculture	P-3
WH_i	Labor input coefficient of the *i*th commodity in household and private agriculture	Exogenous
wi	Annual growth rate of labor inputs in the household sector	Exogenous
wp^{t}	Total working population	Exogenous
wpi	Annual rate of employment of working population	Exogenous

X

$X_l^{(t)}$	Investment in new food processing facilities in period *t*	P-6
$XT_e^{(t)}$	Total production expenses of commodity *e*	P-2

Y

Y	Vector of supply after deducting intermediate inputs and committed demands	CT-3
YO^{t}	Balance of foreign trade	CT-4

α_1	Rate of slaughtering of pigs produced by household and private sector	Exogenous
α_2	Rate of conversion of beef to processed beef	Exogenous
α_3	Rate of conversion of pork to processed pork	Exogenous
α_4	Rate of own processing of grapes produced by the household and private sector	Exogenous
α_5	Annual growth rate of production of other processed food	Exogenous
$\left.\begin{array}{l}\alpha_6\\ \alpha_7\\ \alpha_8\end{array}\right\}$	Parameters of the production function of the rest of the economy	Exogenous
α_9	Share of amortization in expenses of tractor type I use	Exogenous
α_{10}	Share of wages in expenses of tractor type I use	Exogenous
α_{11}	Share of industrial inputs in expense of tractor type I use	Exogenous
α_{12}	Share of amortization in expenses of tractor type II use	Exogenous
α_{13}	Share of wages in expenses of tractor type II use	Exogenous
α_{14}	Share of industrial inputs in expenses of tractor type II use	Exogenous
α_{15}	Share of amortization in expenses of additional equipment use	Exogenous
α_{16}	Share of wages in expenses of additional equipment use	Exogenous
α_{17}	Share of industrial inputs in expenses of additional equipment use	Exogenous
α_{18}	Share of the rest of the economy in the utilization of other crops	Exogenous
$\alpha_{n,n}^{n(t)}$	Rate of intermediate inputs in total output of the rest of the economy	Exogenous
β_1	Rate of change of consumption trend	Exogenous
β_2	Rate of change of share of food and agriculture in total investments	Exogenous
β_3	Rate of change of growth rate of unit wages	Exogenous
β_4	Rate of change of growth rate of community consumption	Exogenous
β_5	Rate of change of growth rate of consumption	Exogenous
β_6	Change of income tax rate of rest of the economy	Exogenous
β_7	Change of income tax rate of socialist agriculture	Exogenous
β_8	Change of income tax rate of food processing	Exogenous

β_9	Change of rate of centralized part of depreciation from rest of economy	Exogenous
β_{10}	Change rate of centralized part of depreciation from socialist agriculture	Exogenous
β_{11}	Change of rate of centralized part of depreciation from food processing	Exogenous
β_{12}	Change of desired upper and lower bound of planned growth rate of GNP	Exogenous
$\gamma_i^{h(t)}$	Yield of commodity *i*	P-2, P-3
$\delta 1_i$	Change of producer price in percent of previous price	Exogenous
$\delta 2_i$	Change of consumer price in percent of previous price	Exogenous
$\epsilon 1$	Allowed deviation between planned and actual buying power	Exogenous
$\epsilon 2$	Allowed deviation from planned growth rate of consumption	Exogenous
λ_{1-32}	Conversion rates in food processing	Exogenous
$\mu_{j,i}$	Resource requirement coefficient in household and private agriculture	Exogenous
$\rho_i^{(t)}$	Share of commodity *i* in planned consumer expenditure	GM-P-2, CT-2
$h\rho_i^{(t)}$	Share of commodity *i* in production capacities of household and private sector	P-1

KENYAN AGRICULTURE: TOWARD 2000

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SUMMARY

OVERVIEW

By the year 2000 the population of Kenya is expected to double to about 30 million. However, even then the population will remain predominantly rural, 73% being the current estimate. The majority of the rural population today consists of smallholders, and this is expected to continue to be the case.

By conventional measures the national income is heavily skewed. For Kenya as a whole the Gini coefficient (see Appendix) is 0.61. A closer examination indicates that, while there is a small number of urban poor in absolute terms, most of the population live in rural households; here the income distribution is more egalitarian, the Gini coefficient being 0.49.

Production Structure

The production structure is vastly different for smallholders and large farms, in terms of both the technology used and the crops grown. Most smallholders grow maize largely for home consumption. This is the principal staple in the country except for some areas in the west where cassava is common. The smallholders typically intercrop, usually with beans or pulses, and use virtually no modern inputs; they are also significant producers of millet and sorghum. Large farms tend to place emphasis on the production of wheat and export crops, such as coffee, tea, and sisal; they also produce a significant share of the marketed maize.

Demand

Maize can be expected to remain the principal crop up until 2000, but substantial increases in demand are anticipated for wheat, rice, sugar, meat, and oils. The higher demand levels are expected primarily owing to the doubling of the population and a per capita income increase of about 27%, while changes in the composition of demand will be much influenced by increasing urbanization.

Production

Higher acreages, greater yields, and improved technology are expected to increase domestic production levels to meet this demand. Most of the gains are expected from higher yields, which will entail substantial increases in inputs. The analysis suggests that all these expectations will be within the realm of technical feasibility, but that institutional factors may be limiting.

Nutritional Status

One of the measures of success of agricultural development is its ability to satisfy the population's nutritional needs. Presently it is estimated that 16% of the population (2.2 million people) are below the datum of 1.2 times the calorie intake for the basal metabolism rate. If present planning objectives are achieved and continue being until 2000, there will be more people below this datum by then (3 million), but they will represent a smaller proportion of the population (10%). Thus, while expenditure growth alone – even the substantial growth postulated of 27% – will alleviate much of the mild-to-moderate malnutrition, it will not eliminate the more severe category. For this group of 10% of the population more direct intervention will be needed.

Consumption–Production Balance

This study suggests that supplies will be adequate to meet domestic demands for maize, millet, sorghum, potatoes, fruit, and vegetables. There are possible shortfalls for wheat, rice, meat, and oils. The wheat supply can be augmented by a modest shift in policy, while meat will most likely require significantly higher producer and consumer prices. Barring a major policy shift, Kenya will need to import rice (about 60 tons per year) and oils. Kenya will still have significant surpluses of its traditional export crops, coffee and tea, and, with a continuation of present policies, a similar surplus for sugar.

This overall consumption–production balance should be achievable with some increases in investment, particularly for improved marketing and distribution facilities, together with land improvement, together with incentives to encourage the move toward higher yields and improved technology. The burden on the balance of payments will not be disproportionately large.

Policy

Policies to achieve this require higher farmgate prices, which should be so designed as to moderate the impact on consumer prices. Since Kenya does not favor consumer subsidies and at the same time seeks to avoid an increased fiscal burden, it faces a dilemma. The analysis suggests some possibilities for trimming the overhead costs of marketing boards and tilting transport tariffs to favor smallholder crops. Similarly, policies directed toward these crops (maize, beans, and pulses) would be self-focusing in that they would favor positive redistribution. These could also be accompanied by noneconomic incentives, such as improved water supply.

For redistribution a number of possibilities are indicated: some land redistribution and reorienting of extension services toward smallholder crops and smallholder technology. Kenya has demonstrated the ability to mount an effective smallholder extension service for some crops, with positive results. It remains to be seen whether this can be extended further to the great majority of smallholders who produce largely for subsistence. It is these rather ephemeral issues of management and institutional structure that pose the biggest problems. There seem to be few problems outside the feasible range of current technical possibilities.

Ironically, the present low yields and the lack of modern inputs offer great potential for improvement, but the social issues are more intractable. The increasing population pressure, with its concomitant increasing food demand, land fragmentation, and employment needs, poses major challenges.

For answers one may seek outside the immediate realm of agriculture. While the whole psychological structure in Kenya is largely pronatalist, the overall educational milieu, strongly influenced by the colonial period, supports a value system in which agricultural employment is ranked rather low.

However, the achievements in the short time since independence suggest that Kenyans can adapt to face a challenge. The rhetoric of the present plan certainly holds promise. It remains to be seen whether the reality will match the promise.

SOME SUPPORTING DETAILS

There are a number of the details that support the summary overview and are of general interest. The purpose of this section of the summary is to set them forth.

Production Targets for 2000

The production target for maize in the FAO study for the year 2000 is 4559 thousand tonnes (metric tons, MT); this estimate arises from the postulate that 1857 thousand hectares (ha) of land will have an average yield of 2.46 MT/ha.

Most of the maize in Kenya is presently produced by smallholders (see Table 32). Their yields vary significantly from less than 0.5 MT/ha for local varieties using virtually no modern inputs to levels close to 4 MT/ha for the most advanced smallholders using hybrid seeds and fertilizer. The area under hybrid maize has increased at a rate of about 60,000–70,000 ha/year since this was introduced around 1970. Present policies, which the current plan is strengthening, should support this trend.

The maize target is feasible if this trend is maintained, as is envisaged in current policies.

Another major question mark is the FAO coffee and tea estimates. In this report we suggest that the additional areas they assume are probably too high. Most area expansion will benefit smallholders, but most informed estimates do not support the FAO area estimates.

Wheat, which is produced by large farms, will need higher producer prices to achieve a 100% yield increase. Meat prices should also rise at the producer and consumer levels. Except for rice, therefore, the principal FAO production targets can be achieved without any major new policy initiatives to favor the smallholders. However, the situation of the smallholders could be improved by accelerating the present trends.

Implications for Crop Yields

Smallholder and large-farm crops differ in many ways (see Table 30). Of the large-farm contribution to the agricultural gross domestic product, 80% comes from the plantations, primarily growing coffee, tea, and sisal. For smallholders the important crops are maize, millet and sorghum.

- For maize, the smallholders' average yield should double, while the additional contribution from large-scale farmers should not be critical.
- For tea and coffee, smallholder yields are presently much lower than those of large-scale farmers, primarily because the large-scale farmers occupy more productive land. However, for tea many of the smallholder yields have been improving rapidly under current policy measures geared toward extension and input availability.
- Wheat will need a doubling of yield. Since this is a large-farm crop, policy makers will have to consider the distributional impact of higher producer prices.
- FAO livestock production targets should be exceeded. However, it is unlikely that Kenya will allow imports to rise to the FAO estimate of 387 MT. The policy will most likely be a combination of higher producer and consumer prices.

Income Distribution and Poverty Effects

The large-farm areas will gain in absolute terms because of higher producer prices for wheat and meat. However, the main source of income will be determined by world market prices for coffee, tea, and sisal.

The smallholders will gain because of higher maize production and higher meat prices. However, most of these gains will be offset by the 4% population growth rate.

The pastoralists will benefit from higher meat prices.

The policies to meet the production goals will therefore make little change in the present income distribution. The improved infrastructure should modestly ease poverty.

Equity

If the aim is to increase equity, it may be desirable to consider the possibility of making land available to the low income groups. According to the estimates of land distribution given in Table 30, the smallholder farms with 10–11 million people have sizes of up to about 10 ha but average a little over 2 ha. They typically grow maize and beans for subsistence. The smaller ones (less than 2 ha) have a few animals; the larger ones produce some surplus maize and tend to have more livestock.

A group of farms not covered in the usual surveys, the so-called "gap farms", are believed to be about 20–50 ha in size. These are understood to be similar to the larger of the smallholder farms, but the land is generally not as good, and there is consequently a lower population density. They tend to have more animals.

The large farms consist of mixed farms, plantations, and ranches. The ranch land is generally of low potential. Plantations primarily grow cash crops such as coffee, tea, and sisal. The mixed farms have high and medium potential land. About 62% of this area has been bought by groups and has been informally and often illegally subdivided without government control. However, this subdivision has now been legalized.

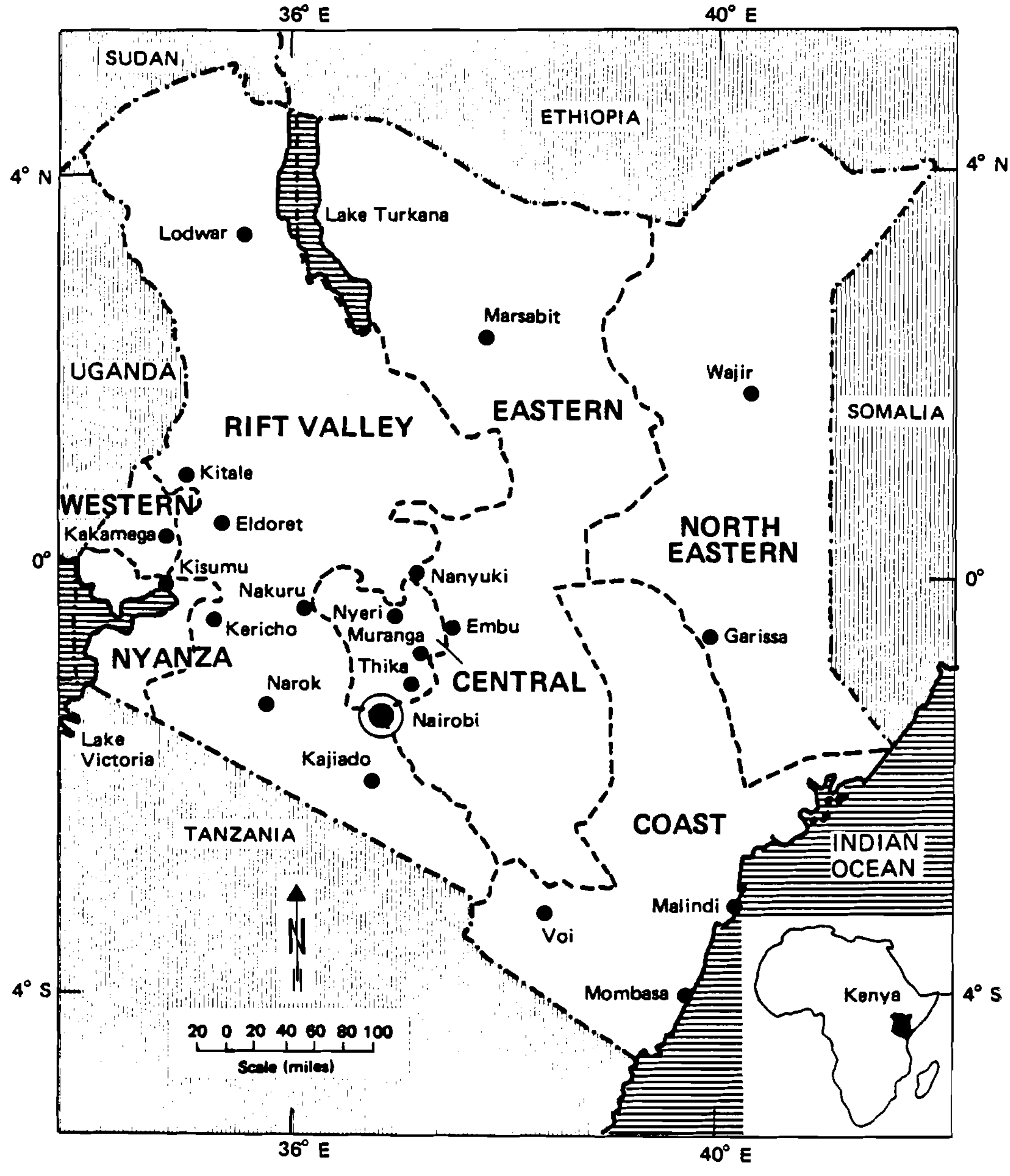
Available Land

There are only about 300,000 ha of suitable land in the large-mixed-farm category that might be used for redistribution. Other lands that might be available include the Narok Agricultural Development Project, where there are an estimated 250,000 ha of high potential land. Additional land may become available in the medium to long term through drainage and irrigation; however, as this analysis indicates, the costs are prohibitive at the moment, and little can be expected from this source. The redistribution of 200,000 ha from large plantations could also be considered, but the political and institutional factors would be major obstacles.

In summary, in the near to short term at most 500,000 ha could be distributed to the low income groups if the political and institutional difficulties could be overcome.

A Land Distribution Experiment

Land holding is a major determinant of total income for smallholders, though activities outside the holding contribute about 50% of income. Let us consider an experiment whereby the 500,000 ha are distributed to the pastoralists, the landless, squatters (1.3



The Republic of Kenya. (Source: The World Bank, 1980.)

million), and the poorest smallholders (3.5 million) – that is, the bottom 40% in the rural area, about 680,000 households. On average they would receive 0.74 ha per household. This in turn suggests that each household would have an additional annual income of about 1900 Kenya shillings (KSh), or about 270 KSh per capita. This would produce a major improvement in nutrition similar to the effect of the major redistribution scenario (236 KSh) discussed in this report. The proportion of malnourished would fall from 33% to 15%, while those below the datum of 1.2 times the basal metabolism rate would fall from 17% to 6.5%.

Thus a land distribution of this magnitude could have a major impact on the low income groups. Political feasibility, however, is the key question.

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1 INTRODUCTION

1.1 Background

Currently Kenya is at an extremely interesting juncture in its history. For the fifteen years following independence in 1963 Kenya had one President, Jomo Kenyatta. In this period the total output of goods and services more than tripled. Many landless families were settled, while colonial prohibitions on Africans from engaging in various forms of economic activity were removed. It was a period of rapid growth, with an increase in real per capita consumption of more than 60%. While the concomitant structural change benefited most of the population, inevitably some groups prospered more than others.

1.2 The Current Plan

In preparing the current plan (1979–83) the government sought ways of rectifying some of these problems by placing greater emphasis on equity and distributional issues. This thrust was given greater emphasis when President Moi assumed office. In his first few months he proposed innovative policies whose implications cannot be fully gauged at this stage. These included a mandated 10% increase in employment by 1979, making everybody literate by 1983, and making free milk available to all schoolchildren*. At this time of change it seems particularly appropriate to take a critical look at agriculture and the policies that mold it. First the overall economy is considered briefly.

1.3 General Economic Considerations – 1976

In 1976 the population of Kenya was estimated at 13.75 million of whom 86.7% lived in rural areas. The gross domestic product was K£1263 million** or K£91.8 per capita, of which 38% was contributed by agriculture. Kenya has a land area of 57 million hectares, of which 6.84 million hectares, or about 12% of the total area, are classified as

*Owing to severe shortages in 1980 this program had to be severely curtailed.
**K£1 equals approximately US$2.65 (May 1979).

high potential agricultural land. This implies that at present Kenya has about 0.49 hectares per capita of high potential land equivalents. If the present high population growth rate of about 3.5% per year* continues then at the turn of the century the per capita high potential land equivalents will fall to 0.2–0.3 ha per capita. However, there are many variations in endowment between different parts of the country and in the purchasing powers of various groups. One of the more obvious differences is that between urban and rural dwellers, for whom there are marked differences in both production and consumption patterns. Similarly, the institutional and behavioral patterns vary greatly between different ethnic groups, from the coast Moslem to the Masai pastoralist. In a short report such as this it is not feasible to disaggregate all the significant variations.

The report, referred to by us as the Kenya Case Study (KCS), has five sections in addition to this Introduction.

In Section 2 we discuss the current economic situation by analyzing the composition of the national product and suggesting what structural changes may be expected by the year 2000. These changes will be strongly influenced by population growth and increasing urbanization.

Section 3 is devoted to the analysis of food demand. The base year (1976) estimates of a number of sources are reviewed. The demand for the year 2000 is then estimated. This is done for a number of scenarios and for various assumptions about population and income growth rates.

In Section 4 the resource base for agriculture is discussed, together with some of the options for increasing output.

Section 5 deals with production estimates for most agricultural commodities. Each group is discussed and estimates are made for the year 2000. Sources of growth are identified and some of the relevant policy measures are discussed.

Section 6 seeks a synthesis. Production and consumption estimates are compared. Some of the implications for income distribution and nutritional status are considered. Finally, some suggestions on possible policy directions are offered.

2 THE ECONOMIC SITUATION

The current economic situation and some of its underlying dynamics are briefly discussed before we focus on agriculture and on food in particular. The gross domestic product by industrial origin, together with that projected for 1983, is given in Table 1 for 1976. Note the large contribution, 38%, from agriculture. This is expected to fall to 34.1% by 1983, primarily because of the relatively low growth rate projected for the semimonetary sector. The manufacturing, building, and construction sectors are expected to increase their shares to 15.8% and 4.4% respectively. More than 80% of the productive work force is located in rural areas, agriculture providing a major share of the opportunities to generate purchasing power. Because of the lower-than-average value added contributed by the workers in agriculture, this sector has a much larger share of the labor force than it does in the total national product.

*While the official rate is 3.5%, the Economic Survey (1979) suggested that the growth rate may be as high as 3.9%.

TABLE 1 Gross domestic product by industrial origin: actual 1976; projected 1983[a].

	K£ million in 1976 prices		Annual growth (%)		Share of total (%)	
			Actual	Target		
	1976	1983	1972–76	1976–83	1976	1983
Enterprises and nonprofit institutions						
Agriculture	219.64	341.30	1.5	6.5	17.4	17.6
Forestry	6.33	10.70	5.9	7.8	0.5	0.6
Fishing	2.36	3.20	0.2	4.5	0.2	0.2
Mining and quarrying	4.15	7.10	11.2	8.0	0.3	0.4
Manufacturing	167.41	306.20	9.4	9.0	13.3	15.8
Electricity and water	14.20	24.30	10.1	8.0	1.1	1.3
Building and construction	46.20	84.50	−4.7	9.0	3.7	4.4
Wholesale, retail trade, etc.	144.46	211.50	2.0	5.6	11.4	10.9
Transport, storage and communications	69.15	109.60	4.1	6.8	5.5	5.7
Finance, insurance, real estate, etc.	68.03	114.30	9.9	7.7	5.4	5.9
Ownership of dwellings	46.13	69.40	2.4	6.0	3.7	3.6
Other services	24.84	38.10	5.1	6.3	2.0	2.0
TOTAL ENTERPRISES	812.90	1320.20	4.2	7.2	64.4	68.3
Private household (domestic services)	10.93	21.30	13.6	10.0	0.9	1.1
Producers of government services	178.91	281.20	6.7	6.7	14.2	14.5
TOTAL MONETARY SECTOR	1002.74	1622.70	4.8	7.1	79.4	83.9
Semimonetary sector	260.11	311.30	0.8	2.6	20.6	16.1
TOTAL GDP AT FACTOR COST	1262.85	1934.00	4.0	6.3	100.0	100.0
Add (+) indirect business taxes	167.00	268.20	−4.1	7.0	13.2	13.8
Less (−) subsidies	−0.77	−8.50	–	–	–	−0.4
GDP AT MARKET PRICES	1429.08	2193.70	2.9	6.3	113.2	113.4

[a]SOURCE: Kenya Development Plan, 1979–83.

2.1 Changes in Structure

Since independence the most notable changes in the composition of the gross domestic product (GDP) have resulted from the steady decline in the combined agriculture and semimonetary share, particularly in the semimonetary component. These changes are summarized in Table 2. If the historic trend continues, then by the year 2000 the share of agriculture should fall to around 27.6% even then including a 10.7% share from the semimonetary economy. It is estimated that the manufacturing, building, and construction sectors will show a dramatic rise to 26.7%. The shares for other enterprises and for government are expected to maintain roughly the same levels. However, the composition will reflect a number of changes. Evidence cited by Kuznets (1966) strongly suggests that those services associated with the production of commodities (power and communications) will steadily grow in importance and that the degree of processing for various foodstuffs will increase.

TABLE 2 Gross domestic product at factor cost -- sector shares.

Industry sector	Sector share in GDP (%) by year 1964[a]	1976[b]	1983[c]	2000[d]
Semimonetary economy	27.0	20.6	16.5	10.7
Enterprises				
Agriculture	16.1	17.4	17.6	16.9
Manufacturing, building, and construction	12.4	17.0	20.2	26.7
Other enterprises[e]	31.6	30.8	31.6	31.6
Government	12.9	14.2	14.1	14.1
TOTAL	100.0	100.0	100.0	100.0

[a]In 1964 prices: Economic Survey, 1975.
[b]1976, 1983, and 2000 figures are in 1976 prices.
[c]1983 official targets: Kenya Development Plan, 1976–83.
[d]The year 2000 figures are estimates based on historical trends from 1964.
[e]Figures include private households.

2.2 Income Distribution

There have been a number of studies of income distribution in Kenya: the International Labour Organization (1972), Ng'ethe (1976), Bigsten (1977), Lijoodi and Ruthenberg (1978), Hazlewood (1978), Crawford and Thorbecke (1978), and Kaplinsky (forthcoming). In view of the wide variations in sociocultural conditions, it is not clear that an aggregate measure of distribution at the national level is very meaningful. At the very least it seems that urban and rural areas should be examined separately. Nevertheless, the ramifications of income redistribution at the national level are considered in Section 5.

Population estimates are given in Table 3. We note that in 1976, of a total population of 13.75 million, the urban population was estimated at 1.83 million, or 13.3% of

TABLE 3 Estimated rural and urban populations, in millions[a].

	Population in millions, by year 1969[b]	1976	1983	2000 (low)	2000 (high)	2000 (medium)
Rural	9.83	11.92	14.47	21.05	24.42	22.73
Urban	1.11	1.83	3.00	7.13	9.70	8.42
TOTAL	10.94	13.75	17.47	28.18	34.12	31.15

[a]Source: the urban estimates are given in Ministry of Finance and Planning (October 1974), Population Projections During 1969–2000. The total estimates are from the Central Bureau of Statistics – high projections assume a constant fertility rate of 7.6, while the lower estimate assumes a reduction in fertility of 40% from 1981 onwards.
[b]1969 was census year.

the total. The total population is expected to increase to at least 28 million by the year 2000. In recent years Kenya has been experiencing rapid population growth, at a rate in the neighborhood of 3.5% per year*. If socioeconomic conditions continue to improve this rate may fall a little, but estimates indicate that unless some major catastrophe occurs there will be a population of around 30 million by the year 2000. It is estimated that the urban population will increase to more than 25% of the total by that time. This will result from a number of factors. The structural change in the economy together with current investment policy indicates that more job opportunities will be available in urban areas. A number of towns will also reach the size at which they will be reclassified into the urban category.

2.3 Urban–Rural Differences

In view of the large differences between urban and rural populations, total GDP was divided between the two and then scaled down to the official gross income level. This gave K£478 million and K£556 million for urban and rural categories respectively**. The rural component was then further disaggregated.

It should be noted (see Table 4) that the vast majority of the rural dwellers are smallholders with modest incomes. Their economic characteristics are discussed in more detail

TABLE 4 Rural income in 1976[a].

Occupation group	Population (millions)	Income (K£ million)	Average per capita income (K£ per annum)
Smallholders	10.11	341	33.7
Pastoralists, landless and squatters	1.29	21	16.3
Large and gap farms, professional, and government service	0.52	194	373.1
TOTAL	11.92	556	46.64

[a]Estimates based on Integrated Rural Survey 1 (IRS1), 1974–75. This survey underestimated the Rift Valley and did not include the North Eastern province.

in the sectors on demand and production. However, it is evident that nonfarm income plays a major role for the "wealthier" smallholders. This component tends to be masked by the average per capita income figure of K£33.7 per annum. There are also noticeable regional differences, those in the Rift Valley and Central provinces being more affluent (Lijoodi and Ruthenberg, 1978). In the production section it is indicated that production by smallholders is considerably different in type of crop and technology from that of

*Recent estimates suggest that the figure could be as high as 3.9% (Economic Survey, 1979). See also Central Bureau of Statistics (November 1979).

**These estimates were obtained with the assistance of the National Accounts Section of the Central Bureau of Statistics.

large farms. These distinctive features offer some possibilities for directing policy to favor the smallholders. The smallholder data is that given in IRS1, adjusted for inflation. The estimate for the remaining category is based on assuming that their incomes are about the same as those of the lower 40% of the smallholder class. An estimate of the coarse distribution is then obtained. The lowest 40% of the rural population are estimated to receive 14% of rural income, while the upper 20% receive 54%. This type of estimate tends to mask the fact that the top 5% receive more than 30% of the income. However, the approach adopted is to be used for demand estimates and provides a reasonable degree of disaggregation for this purpose. The estimated income distribution is given in Tables 5 and 6. The distribution of expenditure is not so skewed because of tax and transfer effects together with the saving pattern – negative at the lower end and strongly positive at the upper end.

TABLE 5 Rural income distribution in 1976[a].

Income group (%)	Income (K£ million)	Per capita income (K£ per annum)	Share of population	Share of income
0–40 (lowest)	78	16.4	0.4	0.14
40–80 (middle group)	179	37.5	0.4	0.32
80–100 (upper group)	299	125.4	0.2	0.54
TOTAL	556	46.6	1.0	1.00

[a]The lowest 40% of incomes are obtained by combining those of the 1.29 million pastoralists and others with the 3.48 million lowest smallholder incomes given in the Integrated Rural Survey 1 (IRS1). The middle 40% are also obtained from the IRS1 data, the upper 20% then being given as residual.

TABLE 6 Urban income distribution in 1976[a].

Income group	Income (K£ million)	Per capita income (K£ per annum)	Share of population	Share of income
0–40	51	69	0.4	0.11
40–80	177	242	0.4	0.37
80–100	250	683	0.2	0.52
TOTAL	478	261	1.0	1.00

[a]Based on data from the Urban Food Purchasing Survey (1977).

2.4 Income Distribution – Urban

An estimate of the income distribution for urban areas is based on a recent Urban Food Purchasing Survey (Casley and Marchant, 1977). This study primarily dealt with households with incomes below K£125 per month. It also excluded single-member households. If this omission is adjusted for, it is estimated that the lowest 75% of the urban population have a total annual income of about K£180 million, which suggests that K£298 million goes to the upper 25%. On using the data from the urban survey, a log–log

Pareto-type plot suggests a distribution of the form shown in Table 6. This distribution indicates that the share of total urban income accruing to the urban poor is lower than that of rural income going to the rural poor. However, urban incomes are on average five times greater than those in rural areas.

Thus as migration from rural to urban areas continues it will exert a strong influence on the overall national income distribution. Since the lower end of the national income spectrum predominantly represents rural dwellers, and also because per capita incomes are growing faster in the urban sector, the overall impact of this increasing urbanization will be an increased disparity in income distribution. This is discussed in more detail in Section 5.

2.5 Conclusions

If the analysis is restricted to purely economic considerations, then recent historical trends suggest broad patterns that are likely to evolve by the year 2000.

- The structure of the economy will reflect a significant change in the composition of the GDP. This will result from the semimonetary sector declining from the 1976 share of 20.6% to 10.7% while the total share of agriculture falls from 38% to 27.6%. Countervailing this will be an increase in the manufacturing, building, and construction sector from 17% in 1976 to an estimated 26.7% by 2000. Within each sector, the composition will change. For example, for the food sector there will be a larger component of value added, owing to greater processing.
- There will be an increase in population from the 1976 figure of 13.75 million to about 30 million, the urban population increasing from less than 2 million in 1976 to about 8 million.
- There will be an increased disparity in income distribution if present policies continue, owing to the relatively greater increase in urban population. However, even by the year 2000 the vast majority of the population will still live in rural areas and will still predominantly be smallholders.

These patterns are suggested primarily by the current economic situation and the trends since independence in 1963. In making these deductions we do not countenance any major shift in the sociopolitical milieu. The patterns can be moderated by active policy measures. Before proceeding to consider various policy options, in particular those that relate to food production and food intake, the demand structure is considered in detail.

3 DEMAND PATTERNS

3.1 Introduction

In Kenya demand patterns differ between ecological zones and provinces, besides exhibiting the striking differences one might expect between urban and rural areas. This is to be expected in view of the large subsistence or near-subsistence population and the large intersectoral variations. Average incomes of urban dwellers are typically five times as high as those in rural areas. Another major factor is that rural consumption patterns include a large component of home production. The urban population will be considered here, and then the rural population. These will then be combined to produce a national estimate of demand.

General Trends in Consumption

During the course of development, demand patterns in most countries tend to show a number of broadly similar characteristics. In the early stages, when much of the economy may be subsistence, the food share tends to be as high as 70% of total expenditure. This tends to fall over time with rising per capita expenditure. Within the food share the portion accruing to primary agriculture shows an even sharper drop. The other share of demand that seems to show a systematic decline is expenditure for household (domestic) services. Most other components of demand tend to increase their share, even more so their absolute values, over time. Clothing and housing items tend to increase rather slowly, except in certain urban locations, but the greatest increase tends to be in the so-called service sector*. In particular, those services related to improved infrastructure, energy, water, transportation, and distribution increase in relative importance. The thrust of urbanization and the rate at which the urban–rural duality is reduced plays a significant role in shaping future demand patterns.

3.2 Urban Consumption Patterns

The urban analysis is based on a sample of 459 households with a total of 2614 members. The Urban Food Purchasing Survey (Casley and Marchant, 1977) was primarily focused on expenditure patterns of those households with monthly incomes below K£125. The survey also excluded single-member households. It is estimated that at the time of the survey (1977) about 75–80% of all urban households fall into this category. The income level for the various households was also estimated. This allows the approximation of an expenditure function for this group.

Expenditure function – poverty level

A plot of expenditure *versus* income exhibits the conventional pattern: dissaving at the low income end and savings gradually becoming positive with increasing income. The data were first aggregated into income classes and then a linear regression was estimated to approximate the expenditure–income relation. This gives

$$E = 39.21 + 0.75Y \qquad R^2 = 0.97$$

where E is the per capita expenditure per annum and Y is the per capita income per annum, both in Kenya pounds (1977), and R^2 is the coefficient of determination. From this it

*This sector may be considered as the residual after allowing for food, clothing, and housing.

can be estimated that expenditure and income are just equal at a level of K£157 per capita per annum.

This relation allows the estimation of income elasticities from expenditure elasticities. Notice that above K£157 expenditure is less than income, primarily owing to a positive saving propensity, so that income elasticities will be lower than expenditure elasticities. At the lower income levels, at which there is considerable dissaving, the converse is the case.

Expenditure by Income Group

The expenditure shares of three income groups are given in Table 7. The share of food declines from about 50% for low incomes to 24% for high incomes. The trend is even more pronounced if both extremes of the income distribution are examined. Even though the shares fall with income, the actual expenditure on each food item listed increases across income groups. Note in particular the sharp fall in the share spent on the staple maize, and the somewhat less pronounced fall for other grains and for bread.

TABLE 7 Urban per capita expenditure shares in 1977.

Commodity group	Low[a] income	Middle[a] income	High[a] income
1 Dairy produce	8.1	7.6	4.2
2 Maize	8.1	4.7	1.9
3 Other grains (rice)	1.8	2.2	0.6
4 Bread	3.1	2.3	1.4
5 Meat	8.9	7.8	4.0
6 Fats	2.8	2.0	1.0
7 Sugar	4.9	2.3	1.2
8 Vegetables	2.8	3.6	2.4
9 Fruit and nuts	0.5	1.0	0.9
10 Drinks	0.5	1.1	0.8
11 Roots	0.3	1.0	0.8
12 Other foods	0.4	0.5	0.4
Total food	44.6	37.3	20.7
Food outside home	4.9	4.6	3.3
Other expenditure	50.5	58.1	76.0
TOTAL	100.0	100.0	100.0

[a]The categories chosen have per capita annual incomes of K£63, K£160, and K£376 respectively in K£ (1977).

SOURCE: Computed from data collected by Casley and Marchant (1977) for the Urban Food Purchasing Survey.

Quantities Consumed

Price and quantity information was not collected in this survey but some measures may be inferred by imputing prevailing Nairobi prices. The estimates are given in Table 8. These categories are aggregated and the price estimated should probably be slightly lower for the low income group and somewhat higher for the upper end to reflect the shift in both the quality and the composition with income.

TABLE 8 Urban per capita consumption in 1977.

Commodity group	Price[a] (Kenya shillings per kilo)	Per capita annual consumption (kg), by income group			
		Low	Medium	High	Average
1 Dairy produce[b]	2.6 (per liter milk)	57.3	99.8	146.1	92.0
2 Maize	1.6 (maize, meal, and flour)	93.4	100.8	108.2	99.5
3 Other grains	3.4 (rice)	9.9	16.0	16.0	13.6
4 Bread	3.0	18.8	25.3	41.7	25.6
5 Meat	7.0 (beef, goat, and fish)	23.1	38.2	51.0	34.7
6 Fats	11.0 (average per liter)	4.6	6.1	8.3	6.7
7 Sugar[c]	4.5	19.7	20.2	24.7	20.9
8 Pulses	2.25 (beans, peas)	10.5	12.9	24.2	14.2
9 Vegetables	3.0	17.0	41.1	71.8	37.6
10 Potatoes	2.0	7.9	15.2	29.9	15.2
11 Cassava	1.0	2.0	3.5	4.5	3.1

[a]These prices are estimates from gazetted prices and prevailing Nairobi retail prices in late 1977. The aim is to reflect the composition of each of the categories. Shah (1978) has examined some of the price effects: in particular, the manner in which the price per unit quantity varies from low to high income consumers.
[b]In milk equivalent: probably about 60% is consumed as whole milk.
[c]In sugar equivalent.

Elasticity Estimate – Urban

A number of authors have estimated elasticities for Kenya. Shah (1978) tried a number of different functional forms and also a disaggregation by different urban locations. Massel and Heyer (1969) made an earlier study based on a sample of 324 middle income urban households. The estimates in this study were based on the data made available in the Urban Food Purchasing Survey (Casley and Marchant, 1977). An aggregate estimate was computed for each of 27 expenditure groups. These are given in Table 9. The lower household size at the upper end may be used to give some indication of variation by income class. These expenditure elasticities differ significantly from income elasticity estimates. Income elasticity values would be somewhat less at the upper income levels, but greater at the lower end where there is considerable dissaving. All groups are aggregated and estimates are obtained by log–log regressions of the form

$$\log E_i = a_i + b_i \log X + c_i \log H$$

where E_i is the annual expenditure per capita on commodity i,
X is the total annual expenditure per capita, and
H is the household size.

This yielded estimates for expenditure and household elasticity for each commodity. The expenditure elasticity value for food, 0.74, is a little higher than would be expected from similar studies in other countries, while the household value, 0.10, suggests that per

TABLE 9 Urban expenditure and household size elasticities (double log)[a] (the figures in parentheses are the standard errors of the estimates).

Expenditure group	Expenditure elasticity[b]	Household size elasticity[b]
1 Loans and gifts	4.22 (0.87)	7.40 (2.23)
2 Rent	0.85 (0.31)	−1.50 (0.80)
3 Fees/licenses	2.72 (0.48)	4.34 (1.24)
4 Services	1.44 (0.26)	−0.93 (0.67)
5 Total regular expenses	1.60 (0.09)	0.58 (0.22)
6 Cleaning materials	0.85 (0.25)	0.43 (0.68)
7 Regular nonfood items	1.14 (0.15)	0.06 (0.37)
8 Food etc. consumed out of house	0.31 (0.54)	−1.69 (1.38)
9 Total regular purchases	0.74 (0.12)	−0.35 (0.31)
10 Meat and fish	0.93 (0.15)	0.72 (0.38)
11 Dairy produce	0.98 (0.14)	−0.07 (0.36)
12 Edible fats	0.64 (0.27)	0.41 (0.70)
13 Sugar and sweets	0.32 (0.14)	0.36 (0.36)
14 Bread	0.97 (0.16)	0.10 (0.41)
15 Maize	0.70 (0.15)	1.12 (0.39)
16 Other grains	1.18 (0.42)	1.03 (1.08)
17 Pulses	0.70 (0.36)	0.51 (0.92)
18 Vegetables	0.43 (0.21)	−1.70 (0.53)
19 Fruit and nuts	0.66 (0.67)	−1.31 (1.72)
20 Roots	0.31 (0.27)	−1.62 (0.67)
21 Drinks and beverages	1.34 (0.21)	−0.15 (0.54)
22 Other foods	0.73 (0.47)	−1.25 (1.21)
23 Total food	0.74 (0.06)	0.09 (0.16)
24 Furniture	1.68 (0.50)	1.31 (1.27)
25 Clothing	1.96 (0.30)	1.63 (0.77)
26 Other major expenses	−0.21 (0.71)	−3.92 (1.82)
27 Total major expenses	1.24 (0.16)	−0.12 (0.41)

[a]Data used in the regressions were from the Urban Food Purchasing Survey (Casley and Marchant, 1977).
[b]For the sample, we sought to exclude those with a household income greater than K£125 per month, and also households with only one member.

capita food expenditure tends to increase slightly with household size. Clothing, at 1.96, is a luxury. Rent follows an expected pattern where per capita costs fall with household size, while furniture, at 1.68, falls in the luxury category.

Within the food group the pattern is somewhat surprising. Meat, at 0.93, is above the total food figure, and given its large share the consumption should rise significantly. The dairy products elasticity, at 0.98, suggests that per capita consumption can be expected to rise steadily with income. Maize and particularly roots are below the total food figure, with household elasticity positive for the former. On the other hand, it is noted that other grains (rice) and bread are more elastic. This suggests that as per capita income rises the share of expenditure on wheat and rice increases in relation to that on maize and roots. The expenditure elasticity for sugar, at 0.32, is lower than might be expected, and lower than would be expected from estimates for other countries. Some of this may be attributed to demand being suppressed owing to lack of availability in certain locations. Shah's (1978) estimate is higher. There are strong negative household size elasticities for vegetables and for fruit and nuts, suggesting that higher per capita consumption of these items is associated with a smaller household size.

The rural sector is considered next, and then both sets of estimates are used to predict future demands.

3.3 Rural Consumption Patterns

Rural consumption patterns in Kenya in recent years have been discussed by a number of authors (Shah 1978, Smith 1978). In both instances they relied to a large extent on the IRS1 1974–75 data. This survey included more than 1600 households from the rural smallholder category, which comprises about 73% of the total population. The survey did not seek to cover those living in the Northeastern Province, and there is some evidence that the Rift Valley Province may not have been adequately represented. There is also some feeling that at the time of the survey expenditure levels may have been slightly inflated owing to the particularly good economic performance for agriculture that year. Subject to these qualifications, it does represent the best source of information currently available on consumption patterns in rural Kenya. This is supplemented by data from the Integrated Rural Survey, 1977, and from the Market Information Survey, 1977, reported in Casley and Marchant 1978.

Rural Expenditure Function – Poverty Level

There was an attempt to include income data in this survey, but as usual in surveys of this type they presented many problems. Nevertheless, an expenditure function was estimated by regressing expenditure on income. This produced the conventional S-type pattern – dissaving at the lower end, with expenditure (normalized by income) rising slowly at first then increasing fairly rapidly over an intermediate range and tapering off toward the higher income groups. Smith (1978) carried out a similar analysis and obtained results of a similar nature. A linear regression for various groups gives

$X = 13.3 + 0.41Y$ (all smallholders)

$X = 12.6 + 0.42Y$ (smallholders with Y less than K£30)

$X = 19.9 + 0.31Y$ (smallholders with Y greater than K£30)

where X is the annual per capita expenditure in K£ (1974–75) and Y is the annual per capita income in K£ (1974–75).

Consumption Shares

The general pattern of expenditure by income group is shown in Table 10. Rural Kenyans produce a large proportion of their own consumption, so that the overall composition bears little resemblance to urban patterns in other countries or even within Kenya. Expenditure seems to fall into three approximately equal categories: namely, own produced items, food purchases, and nonfood purchases together with miscellaneous expenses.

TABLE 10 Average value per holding of household consumption, by household income group[a].

Commodity group	Under 0 KSh	0–999 KSh	1000–1999 KSh	2000–2999 KSh	3000–3999 KSh	4000–5999 KSh	6000–7999 KSh	8000–KSh and over	Total, all groups
Own-produced items									
Maize	309	147	213	327	317	418	546	980	386
Finger millet	24	8	15	13	16	20	45	13	17
Sorghum	26	37	39	31	35	70	28	65	43
Beans	94	56	94	125	157	196	320	353	164
English potatoes	85	13	22	92	148	129	363	221	115
Other crops	106	75	122	108	135	151	246	309	152
Beef	24	27	31	13	8	24	19	46	25
Other meat and poultry	68	38	74	83	92	109	161	161	95
Milk	222	59	141	177	285	369	534	798	300
TOTAL CONSUMPTION OF OWN-PRODUCED ITEMS	959	458	751	968	1193	1487	2262	2946	1297
Purchased items									
Dairy produce and eggs	55	26	32	46	60	49	46	66	46
Grains, flours, and root crops	618	335	385	452	610	491	757	580	498
Meat and fish	234	158	177	202	239	267	312	379	236
Fats and oils	121	28	52	60	84	94	135	154	83
Sugar and sweets	219	83	115	154	184	203	230	276	172
Fruit and vegetables	67	48	71	78	122	108	130	98	88
Drinks and beverages	146	86	95	122	139	141	199	252	140
Salt and other flavorings	37	22	29	36	41	33	45	43	35
TOTAL FOOD PURCHASES	1498	786	956	1151	1478	1385	1853	1848	1297
Clothing	494	142	191	249	213	350	482	714	324
Appliances and utensils	31	8	16	14	17	38	33	58	25
Furnishings	69	26	14	35	22	47	59	92	40
Miscellaneous purchases	152	81	113	138	157	178	211	286	158
TOTAL NONFOOD PURCHASES	746	256	334	437	410	613	784	1151	547
Miscellaneous expenses	488	110	125	165	283	406	719	560	309
TOTAL CASH CONSUMPTION	2732	1153	1414	1753	2171	2405	3356	3559	2153
TOTAL CONSUMPTION	3691	1611	2165	2721	3364	3892	5618	6505	3450
NUMBER OF HOLDINGS	98,982	175,057	332,813	204,972	174,002	200,501	117,919	179,176	1,483,422

[a]Incomes are in Kenya shillings (1974–75) per household per annum.
SOURCE: Integrated Rural Survey, 1974–75.

Expenditure on schooling* or on imputed house rental costs is not included. This latter item is not very large for most rural smallholders. However, the net effect is that the food share is somewhat overstated.

Most smallholders typically produce maize for home consumption. The principal exception to this is in parts of Nyanza, where sorghum dominates – see Table 11. Many sell a portion of their produce to generate cash income; many also have some source of employment. In the low income brackets, the food sold can hardly be termed a surplus in the sense that domestic needs have first been satisfied. This is evident from the steady rise with increasing income of the proportion of food consumption that is domestically produced. Note in particular the low income levels shown in Table 12. From a policy point of view this indicates the need for generating some source of cash income for these groups; otherwise, they are driven to selling much needed food for cash, often at unfavorable prices. The share of total expenditure devoted to food purchases does not increase as rapidly as the other two principal categories, which suggests the perceived necessity for these items.

Rural Consumption – Elasticities

The estimated annual per capita consumption levels are given in Table 13 for rural areas. Maize consumption is estimated to be about 126 kg, of which two thirds is home produced and only one third purchased. It is clearly the principal source of calories and also of protein. Similarly, for milk we find that only 7% is purchased. The principal food items purchased are wheat, fats, and sugar.

Expenditure elasticity estimates for three income groups are given in Tables 14–16, for low, medium, and high income groups. On moving up the income scale, the elasticity for food purchases falls from 0.97 to 0.89 to 0.79. This is in line with the pattern in most countries on moving from subsistence toward some degree of "affluence". Within the food group it is further noted that the elasticities for meat and sugar also fall.

Elasticities for virtually all the own-produced foods fall with income. Typically, the elasticity for milk declines from 1.95 at low income levels to 0.57 at high income levels, suggesting that the poor perceive milk as a luxury.

3.4 Rural–Urban Estimates Combined

From the foregoing analysis we can now produce national estimates of current demand and postulate future demand. The demand for 1976 is first estimated by combining the rural estimates for 1974–75 with the urban estimates based on 1977. For both cases income and population levels are adjusted to 1976 levels.

The data are summarized in Table 17. The differences in the average rural and urban patterns are particularly noticeable. Urban dwellers consume about 20% less maize and virtually no millet or sorghum. However, the urban dweller consumes much more wheat, primarily in the form of bread, and also rice. He also consumes more sugar, fat (mostly cooking oil), and meat. He can enjoy this consumption pattern partly owing to the higher income level he enjoys, but also because of the marketing in urban areas. The rural dweller

*In December 1978 President Moi announced that primary school fees for Standard VI would be abolished; schooling for Standards I–V was already free.

TABLE 11 Percentage distribution of household food consumption by type of food and province[a].

Commodity group	Central	Coast	Eastern	Nyanza	Rift Valley	Western	TOTAL
Own-produced items							
Maize	11.74	12.55	10.76	20.60	24.49	17.55	14.88
Finger millet	0.00	0.00	0.29	0.98	2.22	1.80	0.66
Sorghum	0.00	0.00	0.20	7.01	0.00	1.14	1.66
Beans	7.70	1.26	12.45	1.18	0.23	3.32	6.32
English potatoes	8.60	0.00	7.59	0.00	0.08	0.00	4.43
Other crops	5.97	3.25	8.15	5.05	0.51	5.22	5.86
Beef	0.19	1.76	0.68	0.88	3.20	1.80	0.96
Other meat and poultry	3.01	4.02	3.19	4.07	3.12	5.27	3.66
Milk	11.87	2.76	11.02	11.57	31.90	6.36	11.57
TOTAL CONSUMPTION OF OWN PRODUCE	49.07	25.64	54.34	51.35	65.76	42.50	50.00
Purchased items							
Dairy produce and eggs	2.02	2.79	1.37	1.18	1.09	2.80	1.77
Grains, flour, and root crops	19.56	44.55	23.66	11.23	9.36	16.79	19.20
Meat and fish	4.71	9.11	3.75	19.27	6.59	14.52	9.10
Fats and oils	5.23	2.41	2.97	2.31	0.78	2.47	3.20
Sugar and sweets	8.15	6.85	4.20	5.89	7.53	9.25	6.63
Fruit and vegetables	4.04	3.02	3.49	3.29	1.25	3.13	3.39
Drinks and beverages	6.29	4.59	4.37	4.12	6.71	7.21	5.40
Salt and other flavorings	0.93	1.03	1.79	1.42	0.94	1.28	1.35
TOTAL FOOD PURCHASES	50.93	74.36	45.66	48.65	34.24	57.50	50.00
TOTAL FOOD CONSUMPTION	100.00	100.00	100.00	100.00	100.00	100.00	100.00
TOTAL VALUE OF FOOD CONSUMPTION (KSh)	3118	2613	3068	2039	2564	2108	2594

[a]Excludes pastoral and large farm areas.
SOURCE: Integrated Rural Survey, 1974–75.

TABLE 12 Percentage distribution of household food consumption by type of food and household income group.

Commodity group	Under 0 KSh	0–999 KSh	1000–1999 KSh	2000–2999 KSh	3000–3999 KSh	4000–5999 KSh	6000–7999 KSh	8000 KSh and over	TOTAL
Own-produced items									
Maize	12.58	11.82	12.48	15.43	11.87	14.55	13.27	20.44	14.85
Finger millet	0.98	0.64	0.80	0.61	0.60	0.70	1.09	0.27	0.66
Sorghum	1.06	2.97	2.28	1.46	1.31	2.44	0.68	1.36	1.66
Beans	3.83	4.50	5.51	5.90	5.88	6.82	7.78	7.36	6.32
English potatoes	3.46	1.05	1.24	4.34	5.54	4.49	8.82	4.61	4.43
Other crops	4.31	6.03	7.15	5.10	5.05	5.26	5.98	6.45	5.86
Beef	0.98	2.17	1.82	0.61	0.30	0.84	0.46	0.96	0.96
Other meat and poultry	2.77	3.05	4.34	3.92	3.44	3.80	3.91	3.36	3.66
Milk	9.04	4.74	8.26	8.35	10.67	12.85	12.98	16.65	11.57
TOTAL CONSUMPTION OF OWN PRODUCE	39.03	36.82	44.00	45.68	44.66	51.78	54.97	61.45	50.00
Purchased items									
Dairy produce and eggs	2.24	2.09	1.87	2.17	2.25	1.71	1.12	1.38	1.77
Grains, flour, and root crops	25.15	26.93	22.55	21.33	22.84	17.10	18.40	12.10	19.20
Meat and fish	9.52	12.70	10.37	9.53	8.95	9.30	7.58	7.91	9.10
Fats and oils	4.92	2.25	3.05	2.83	3.14	3.27	3.28	3.21	3.20
Sugar and sweets	8.91	6.67	6.74	7.27	6.89	7.07	5.59	5.76	6.63
Fruit and vegetables	2.73	3.86	4.16	3.68	4.57	3.76	3.16	2.04	3.39
Drinks and beverages	5.94	6.91	5.57	5.76	5.20	4.91	4.84	5.26	5.40
Salt and other flavorings	1.51	1.77	1.70	1.70	1.54	1.15	1.09	0.90	1.35
TOTAL FOOD PURCHASES	60.97	63.18	56.00	54.32	55.34	48.22	45.03	33.55	50.00
TOTAL FOOD CONSUMPTION	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
TOTAL VALUE OF CONSUMPTION (KSh)	2457	1244	1707	2119	2671	2872	4115	4794	2594

SOURCE: Integrated Rural Survey, 1974–75.

TABLE 13 Rural consumption levels, 1974–75, by income group.

Commodity group	Price (KSh per kg)	Consumption per capita per annum in kg[a]			
		Low	Medium	High[b]	Average
Own-produced items					
Maize	0.66	43.8	91.2	145.6	83.1
Millet, sorghum	0.5	16.8	25.4	14.4	19.8
Beans	2.1	6.4	15.8	25.8	14.0
Potatoes	0.8	6.8	18.3	78.4	25.7
Meat	3.2	2.7	3.9	10.6	4.7
Milk	0.93	16.7	76.8	125.0	65.7
Vegetables	0.60	7.0	14.8	20.3	12.8
Cassava and other roots[c]	0.40	17.8	33.3	50.3	30.5
Purchased items					
Dairy produce	1.5	3.1	4.5	10.2	5.0
Maize[d]	0.8	60.5	39.5	9.7	41.9
Wheat	2.5	1.1	11.5	23.6	9.8
Other cereals (mostly rice)	2.5		1.1	4.7	1.4
Meat	3.6	7.0	7.9	19.0	9.8
Fat	9.0	0.8	1.5	3.3	1.6
Sugar	2.7	6.2	8.0	22.4	10.2
Vegetables[e]	0.8	6.0	6.9	10.7	7.3

[a]The income groups chosen have average annual per capita incomes of 12.5, 37.5, and 120.0 approximately, in K£ (1974–75).

[b]Some of the quantity levels listed for this group seem high; this may be due to assuming too low a price, or else in some instances the imputed home consumption does not all go to the household members. The figure for own-consumed maize is that for the K£100 per annum income group.

[c]The "other crops" category is assumed to include 50% roots – the remainder being vegetables (30%) and fruit (20%).

[d]Purchased roots and grains are disaggregated as follows: for low incomes, 90% maize, 5% wheat, 5% sorghum; for high incomes, 10% maize, 75% wheat, 15% rice; and for medium incomes, 55%, 40%, and 5%.

[e]These are estimated as 50% of the fruit and vegetable aggregate category.

consumes more potatoes and considerably more cassava. He adjusts to his lower income level by obtaining a large share of his calories through the cheaper sources: millets, sorghum, and cassava.

3.5 National Estimates

An estimate of total national demand for 1976 is also given in Table 17. It is of interest to compare other estimates, in particular those prepared by Aldington (1979) as a food balance sheet for the current government plan. These are given in Table 18, while those developed by the FAO are reproduced in Tables 19 and 20. One should exercise caution in comparing the estimates as the categories do not match exactly; also, the FAO estimate is for 1975. This difference in base year would account for a difference of about 4–6%, depending on whether the commodity in question has a low or high elasticity. Even allowing for this margin there are some differences.

TABLE 14 Expenditure and household size elasticities (double log)[a] for the rural low income[b] group.

Commodity group	Expenditure elasticity[c]	Household size elasticity[c]
Purchased items		
1 Dairy produce	1.18 (0.17)	0.07 (0.19)
2 Grains	1.08 (0.12)	−0.19 (0.13)
3 Meat	1.41 (0.12)	0.33 (0.13)
4 Fats	2.03 (0.16)	0.55 (0.17)
5 Sugar	1.54 (0.12)	0.52 (0.13)
6 Fruit and vegetables	1.16 (0.13)	−0.08 (0.14)
7 Drinks	1.55 (0.10)	0.55 (0.11)
8 Flavoring	1.11 (0.10)	0.10 (0.11)
14 TOTAL FOOD PURCHASES	0.97 (0.03)	−0.09 (0.03)
9 Clothing	2.96 (0.19)	1.68 (0.21)
10 Appliances	1.33 (0.14)	1.02 (0.15)
11 Furnishings	0.98 (0.15)	0.52 (0.16)
12 Fuel	1.17 (0.10)	0.44 (0.11)
13 Miscellaneous	1.05 (0.06)	0.10 (0.07)
15 NONFOOD PURCHASES	1.45 (0.04)	0.20 (0.04)
16 *Own-produced items*	1.00 (0.06)	0.18 (0.07)
17 Livestock	1.30 (0.15)	1.36 (0.17)
18 Milk	1.95 (0.21)	2.65 (0.22)
19 Local maize	0.36 (0.21)	−1.06 (0.23)
20 Hybrid maize	0.62 (0.21)	1.34 (0.23)
21 Millets	0.04 (0.14)	0.33 (0.16)
22 Sorghum	−0.23 (0.15)	−1.07 (0.17)
23 Beans	1.85 (0.20)	0.45 (0.22)
24 Potatoes	0.92 (0.14)	0.23 (0.15)

[a]The computations used data collected for the Intergrated Rural Survey 1, 1974–75. The sample size was 940.
[b]Annual per capita income 0 to 30 in K£ (1974–75).
[c]The figures in parentheses are standard errors for the estimates.

TABLE 15 Expenditure and household size elasticities (double log)[a] for the rural middle income[b] group.

Commodity group	Expenditure elasticity	Household size elasticity
Purchased items		
1 Dairy produce	0.96 (0.23)	−0.60 (0.22)
2 Grains	0.86 (0.13)	−0.10 (0.12)
3 Meat	0.91 (0.13)	0.08 (0.13)
4 Fats	2.14 (0.19)	0.51 (0.18)
5 Sugar	1.06 (0.11)	−0.14 (0.10)
6 Fruit and vegetables	0.92 (0.17)	0.14 (0.17)
7 Drinks	1.20 (0.09)	−0.04 (0.11)
8 Flavoring	0.77 (0.12)	−0.30 (0.11)
14 TOTAL FOOD PURCHASES	0.89 (0.04)	−0.22 (0.04)
9 Clothing	2.42 (0.23)	1.33 (0.23)
10 Appliances	1.56 (0.21)	1.08 (0.20)

TABLE 15 *Continued.*

Commodity group	Expenditure elasticity	Household size elasticity
11 Furnishings	0.51 (0.22)	0.86 (0.21)
12 Fuel	0.96 (0.12)	0.24 (0.12)
13 Miscellaneous	1.08 (0.07)	−0.08 (0.07)
13 NONFOOD PURCHASES	1.58 (0.05)	0.34 (0.53)
16 *Own-produced items*	1.05 (0.07)	0.20 (0.07)
17 Livestock	1.16 (0.20)	0.99 (0.19)
18 Milk	1.23 (0.26)	2.74 (0.25)
19 Local maize	1.15 (0.14)	0.20 (0.14)
20 Hybrid maize	0.59 (0.29)	0.74 (0.28)
21 Millets	−0.28 (0.18)	0.19 (0.17)
22 Sorghum	−0.38 (−0.10)	−0.33 (−0.09)
23 Beans	2.31 (0.26)	0.54 (0.25)
24 Potatoes	1.65 (0.24)	0.87 (0.24)

[a]The computations used data collected for the Integrated Rural Survey 1, 1974–75. The sample size was 588.
[b]Annual per capita income 30 to 100, in K£ (1974–75).
[c]Figures in parentheses are standard errors for the estimates.

Cereals. Wheat, millet and sorghum seem to be in reasonable agreement. The FAO rice paddy figure (which does not allow for about 20% milling loss) should be closer to 40,000 rather than 31,000 tonnes. The principal discrepancy appears for maize. The Kenya Case Study and the Ministry of Agriculture put the figure at about 1.7 million tonnes. The FAO estimate (after adjustment to 1976 values) seems a little low at 1.3 million tonnes.

Potatoes and cassava. The Kenya Case Study and the Ministry of Agriculture estimate potato production at around 350,000 tonnes, while the FAO estimate less than half this. On the other hand, the FAO gives a figure of 800,000 tonnes for sweet potatoes and cassava. The Ministry of Agriculture gives 1.2 million tonnes, while the current study suggests only 370,000 tonnes. Cassava is notoriously difficult to estimate correctly, so it is difficult to see how these differences might be resolved without further field work.

Sugar. The FAO estimate, at 248,000 tonnes (1975), seems too high, but the current study estimate (164,000 tonnes) may have underestimated some sources of sugar consumption, particularly in rural areas. The Ministry of Agriculture estimate of around 200,000 tonnes in 1976 is perhaps about right.

Pulses. The Kenya Case Study omits a number of pulses and obtains a total estimate of 194,000 tonnes. Again, the Ministry of Agriculture estimate, at around 250,000 tonnes, strikes a balance.

Milk. In the light of recent studies (Kenya Ministry of Economic Planning and Community Affairs 1978; Mbaja and de Graaff 1978), the Kenya Case Study estimate of about 1 million tonnes is perhaps nearer the mark. The other two sources possibly underestimate home consumption in rural areas.

Meat and fish. The FAO estimates 236,000 tonnes, of which about 44% is beef and veal, while the Ministry of Agriculture estimates 270,000 tonnes with 47% beef. The Kenya

TABLE 16 Expenditure elasticities[a] for the rural high income group.

Commodity group	Expenditure elasticity
Purchased items	
1 Dairy produce	1.30
2 Grains	1.06
3 Meat	0.47
4 Fats	0.97
5 Sugar	0.65
6 Fruit and vegetables	0.76
7 Drinks	0.69
8 Flavoring	0.53
9 Clothing	1.14
10 Appliances	1.64
11 Furnishings	0.54
12 Fuel	1.52
13 Miscellaneous	1.05
14 TOTAL FOOD PURCHASES	0.79
15 NONFOOD PURCHASES	2.26
16 *Own-produced items*	0.72
17 Livestock	0.77
18 Milk	0.57
19 Local maize	
20 Hybrid maize	0.42
21 Millets	−0.24
22 Sorghum	−0.25
23 Beans	0.94
24 Potatoes	1.03

[a]The computation is based on the regression ($E_i = a + b \log X + c \log H$) for those smallholders with a per capita income greater than K£30 per annum. The elasticity was then computed from $D_{ij} = b_i/E_i$, where E_i is the per capita expenditure by those in the K£75–125 income group. Money values are in K£ (1974–75).

TABLE 17 Food consumption estimates for 1976.

Commodity group	Per capita consumption (kg per annum)			Total national demand (thousand tonnes)
	Rural	Urban	National	
1 Maize	125.6	97.1	121.9	1676
2 Millet, sorghum	19.8	–	17.2	236
3 Wheat	10.0	24.7	11.9	164
4 Other cereals (rice)	1.4	13.1	2.9	40
5 Potatoes	26.2	14.8	24.7	340
6 Cassava and other roots	30.5	3	26	369
7 Sugar	10.4	20.6	11.7	161
8 Pulses	14.2	13.8	14.1	194
9 Milk	72.1	88.6	74.2	1021
10 Meat	15.1	33.6	17.5	241
11 Fat	1.7	6.5	2.4	32
12 Vegetables	20.4	36.9	22.5	310

SOURCE: Urban estimates are based on the Urban Food Purchasing Survey (Casley and Marchant, 1977) while rural estimates are based on Integrated Rural Survey 1 (1974–75) data. Both estimates are adjusted to 1976 values.

TABLE 18 Food balance sheet, 1976 and 1983 (populations: 1976, 13,850,000; 1983, 17,648,000).

Commodity group	Consumable supplies (thousand tonnes)		Consumption per capita per annum		Percent utilized as human food	Grams per head per day		Calories per head per day		Protein, grams per head per day	
	1976	1983	1976	1983		1976	1983	1976	1983	1976	1983
Maize	1634.0	2124.0	118.0	120.0	80	259	263	917	921	23.3	23.7
Other coarse grains	277.0	383.0	20.0	21.6	80	44	47	154	165	3.9	4.2
Wheat flour	140.0	204.0	10.1	11.5	100	28	32	98	112	2.8	3.2
Rice	34.6	47.6	2.5	2.7	100	7	7	25	25	0.5	0.5
Barley	41.6	112.0	–	–	–	–	–	–	–	–	–
Malt	26.6	71.5	–	–	–	–	–	–	–	–	–
Beer	163.0	439.0	11.8	24.8	100	32	68	13	28	–	–
Beans	150.0	213.0	11.0	12.0	93	27	31	80	102	5.3	6.0
Other pulses	98.0	137.0	7.0	7.7	93	13	20	59	65	3.6	4.0
Potatoes	376.0	485.0	25.0	27.4	85	58	64	44	48	1.2	1.3
Other starchy roots	1191.0	1534.0	86.0	86.7	60	142	143	234	236	1.4	1.4
Sugar	195.0	317.0	14.1	17.9	100	39	49	156	196	–	–
Bananas and plantains	209.0	300.0	15.1	16.9	85	35	39	36	40	0.5	0.6
Oilseeds and nuts	35.0	71.0	2.5	4.0	85	6	9	9	13	0.1	0.1
Fruit and vegetables	203.0	280.0	14.7	15.8	80	32	35	15	16	0.2	0.2
Milk and milk products in whole milk equivalent	652.0	928.0	47.1	52.4	100	129	144	83	92	4.1	4.6
Eggs	20.8	29.5	1.5	1.7	88	3.5	4	6	6	0.5	0.5
Beef	128.0	159.0	9.2	9.0	80	20	20	40	40	3.8	3.8
Mutton and goat meat	65.0	82.0	4.7	4.6	74	10	9	15	14	1.6	1.5
Pork	2.7	3.9	0.2	0.2	80	0.8	1	2	2	0.1	0.1
Poultry meat	27.8	38.5	2.0	2.2	80	3	5	6	10	0.6	1.0
Fish	42.4	59.8	3.1	3.4	70	6	7	9	10	1.2	1.3
Oil and fat including butter	44.3	74.0	3.2	4.2	100	9	12	81	100	–	–
TOTAL	–	–	–	–	–	–	–	2082	2241	54.6	58

SOURCE: Kenya Development Plan (1979–83).

TABLE 19 Kenya – projected demand for food: crops (in thousand tonnes) (FAO estimates).

	High hypothesis				Low hypothesis			
Commodity group	1975	1985	1990	2000	1975	1985	1990	2000
Total cereals	1764	2608	3081	4054	1764	2532	3047	4342
Wheat	186	323	440	819	186	280	352	557
Rice paddy	31	52	69	124	31	46	57	89
Barley	–	–	–	–	–	–	–	–
Maize	1290	1889	2173	2551	1290	1862	2239	3137
Oats	2	3	3	5	2	3	3	5
Millet and sorghum	254	340	394	553	254	340	394	553
Other cereals	1	1	2	2	1	1	2	2
Total roots and tubers	943	1392	1705	2541	943	1347	1622	2338
Potatoes	129	211	273	447	129	191	237	359
Sweet potatoes	337	511	636	977	337	486	389	862
Cassava	477	670	796	1117	477	670	796	1117
Total sugar	248	394	563	1066	248	312	410	690
Pulses, nuts, and seeds	298	437	536	798	298	418	500	712
Vegetables	274	456	598	997	274	408	508	780
Fruits (and plantain)	418	704	945	1728	418	623	778	1210
Spices	4	6	8	13	4	5	7	10
Tea	7	12	17	29	7	11	14	21
Coffee	2	3	5	9	2	3	4	6
Vegetable oils	22	39	54	104	22	33	42	67

All data are estimates (March 1978).
Assumptions used in the food demand projections:

	1975		1985		1990		2000
Population (thousands) (UN medium)	13,251		18,605		22,102		31,020
Growth rate		3.5		3.5		3.4	
Total private consumption expenditure							
Low alternative		4.4		5.0		5.0	
High alternative		6.2		7.2		7.2	

TABLE 20 Kenya – projected domestic demand for food: livestock products (in thousand tonnes).

	High hypothesis				Low hypothesis			
Commodity group	1975	1985	1990	2000	1975	1985	1990	2000
Beef and veal	105	192	271	542	105	161	205	234
Mutton and lamb	23	40	56	108	23	34	44	74
Pig meat	5	8	11	19	5	7	9	13
Poultry meat	21	41	60	127	21	33	43	71
Other meat	12	19	24	40	12	17	21	32
Offal	35	55	70	113	35	51	62	93
Eggs	12	23	35	77	12	13	24	41
Whole milk	592	964	1248	2044	592	875	1082	1642
Skim milk	41	100	146	229	41	93	133	196
Animal fats and oils[a]	5	10	16	33	5	9	12	20
Finfish, fresh	20	31	40	64	20	29	35	53
Finfish, processed	15	24	32	55	15	22	27	41

[a]Including butter.
All data are preliminary (March 1978). SOURCE: FAO, Rome.

Case Study gives an aggregate rural consumption, but in urban areas beef accounts for about 54%, fish 24%, and poultry about 8%, the remainder being other meats, principally sheep and goat. In rural areas there is some evidence that the beef share is about 40%, while other meats have a somewhat larger share. This would then yield a national estimate for beef consumption of 105,000 tonnes. If in addition we estimate that in rural areas 10% by weight of this category is fish, then a national estimate for fish of around 33,000 tonnes is obtained.

Fats and oils. The FAO estimate of around 38,000 tonnes (vegetable and animal origin) checks with the Kenya Case Study estimate of 32,000 tonnes. The Ministry of Agriculture estimate of 44,300 tonnes includes butter, and so these figures are reasonably consistent.

Vegetables. Vegetable consumption is particularly difficult to estimate accurately, but the Kenya Case Study estimate of 310,000 tonnes ties in reasonably well with the FAO's 281,000 tonnes (after adjustment) and with the Ministry of Agriculture figures.

In summary, most estimates are in reasonable agreement. However, the FAO maize estimate is perhaps 300,000 tonnes too low. The Kenya Case Study estimate for cassava is probably too low by as much as 50%, while the pulse estimates should probably also be increased by about 25%, as the Integrated Rural Survey data used for the estimate primarily related to beans.

3.6 Future Demand

The estimation of future demand for an economy undergoing change as rapidly as Kenya's is today presents a number of difficulties. The structural changes mentioned earlier are both the result and the cause of variations in economic performance. Invariably, many major transitions do not lend themselves to meticulous forecasting, as in the case of the OPEC oil price increase or the depreciation of the US dollar.

In the specific Kenyan context, one could envisage a major improvement for certain resources; for example, new mineral or oil discoveries, or breakthroughs in veterinary medicine permitting significant increases in livestock production. However, the reality of assessing demand for the year 2000 invariably means being faced with the issues of population, income, and price structure.

Population. In Section 2 it was indicated that the population will be around 30 million by the year 2000. This alone will necessitate a substantial increase in food production, even just to maintain current intake levels. There are those, however, who argue that the consequences of high population growth rates are not all negative. Besides the benefits perceived at the family level, in certain circumstances there may be some positive features at the national level. The cost per capita for a number of services should fall (in real terms); for electric power, better load factors should be achieved; roads and infrastructure should be used more efficiently, while a population of 30 million should provide a large enough domestic market to enable producers to take advantage of economies of scale. This should also cushion the effects of external market fluctuations. However, specifically in Kenya the population is currently increasing extremely rapidly. This is because of a modest increase in fertility in recent years and a precipitous fall in mortality due to improved living conditions. The recent Kenya Fertility Survey (1980) suggests that the crude birth rate may be as high as 54.6 while the crude death rate is 14.2, giving a net population growth rate of 4%. Recent practice in other developing countries (see Johnston 1977 for example) suggests that the fertility rate should be reduced to bring the rates into a more manageable balance. In Kenya this is in line with present government policy, as stated in the Development Plan 1979–83. However, if the policy is to be effective, it will require certain innovations, together with a major effort to change deep-rooted attitudes. Such a change requires a major commitment at all levels of leadership. The Kenya Fertility Survey (1980) says "In spite of a national policy to promote family planning, there is at present little contraceptive practice in Kenya" (Section 7.10, page 142).

Income. In recent years there have been significant gains in per capita income. The government has opted for substantial investment in human capital, which should produce results by 2000. How big an increase can be expected? Few countries have achieved per capita growth rates of more than 2% per annum over an extended period and rarely is the agricultural sector growth rate more than 1% above the population growth rate.

Price structure. Price changes can also play a major role in shaping demand. These changes will depend to some extent on the role of the government. Until recently, government policy in Kenya has avoided consumption subsidies except in cases of severe hardship: in famines caused by inclement weather, or for groups particularly vulnerable for limited periods such as pastoralists being helped to adapt to a more settled lifestyle. The decision by President Moi to embark on a broad national feeding program for schoolchildren signals a major departure from previous approaches. However, the program has run into many difficulties. The normal administrative problems for a program of this magnitude were compounded by a disastrous harvest due to inclement weather. This has resulted in the program's being severely curtailed. Policies of this form can have major repercussions on demand without evident changes in nominal income levels; that is, the recipients' purchasing power increases. However, in order to be effective, such policies have to be well planned and executed. They should also be weighed against other options such as alternative foods or a program to improve health.

Finally, the issue of changes in taste is important. Again, this is difficult to predict. Urban dwellers in particular are likely to be more affected by various promotion campaigns. This is presently evident in the increased consumption of cooking fat, drinks, and beverages; on the other hand, much of the increase in bread consumption may be due to its convenience.

Scenarios for Year 2000

Possible changes in many variables should be considered in estimating demand patterns for the year 2000. Even then the estimates must be hedged because of the many unforeseeable events, both domestic and abroad, that may exert a critical influence. To reduce the task to manageable proportions requires that the most important factors be identified.

At the individual level, where in most societies purchasing power dominates the economic milieu, income (in its broadest sense) and the price structure are critical. For aggregate and especially national estimates, population growth plays an important role. In many developing countries, and especially in Kenya, the degree of urbanization exerts a strong influence, both on incomes and on changes in expenditure patterns. From the plethora of possibilities, five scenarios are chosen in this report. These are summarized in Table 21. Two other scenarios (6 and 7) are discussed in Section 5. These correspond to the FAO low and high alternatives. The properties of each are discussed briefly now and compared with those for the base year, 1976. For this we combined the urban and rural distributions. However, it would be more useful for many issues to discuss these sectors separately.

TABLE 21 Income distribution scenarios.

	Share of income					
		Scenarios for the year 2000				
Share of population (%)	Base year 1976	1	2	3	4	5
0–40	0.092	0.092	0.071	0.069	0.070	0.153
40–60	0.093	0.093	0.090	0.087	0.088	0.123
60–80	0.181	0.181	0.175	0.176	0.176	0.181
80–90	0.177	0.177	0.192	0.188	0.190	0.177
90–100	0.457	0.457	0.472	0.480	0.476	0.366
TOTAL	1.000	1.000	1.000	1.000	1.000	1.000
Per capita annual income in K£ (1976)	75.20	75.20	101.00	107.60	132.70	75.20
Population in millions	13.75	31.15	28.18	34.12	31.15	31.15
GROSS INCOME (billion K£ (1976))	1.03	2.34	2.85	3.67	4.13	2.34

Scenario 1. The distribution of income remains the same as in the base year, the average annual national per capita income is unchanged, while the medium population growth rate is assumed. This scenario might be viewed as a norm for comparing others in the year 2000.

Scenario 2. The distribution of income within urban and rural sectors remains unchanged and within each of these the average annual per capita incomes remain the same. However, because of the relatively higher population growth rate in the urban sector the outcome is a higher national average annual per capita income. The low estimate is assumed for the national population growth rate.

Scenario 3. The same assumptions as in Scenario 2 are made about the urban and rural sectors. However, the high estimate is assumed for the national population growth rate.

Scenario 4. The distribution of income within urban and rural sectors remains unchanged. Within each sector annual per capita income is assumed to grow at 1% per year from 1976 to 2000. The medium estimate is used for the national population growth rate. This scenario probably comes closest to recent trends in urbanization and population growth rate, while the income growth rates are close to current plan targets. This scenario projects an annual growth rate in gross income of 5.9% with a 3.5% population growth rate.

Scenario 6. This is the FAO low alternative. Its assumptions include a population growth remains at the 1976 level, with the medium population growth rate. A redistribution of income is postulated. It is assumed that the share of the upper 10% of the population is reduced by 20% from 0.457 to 0.366. The income derived from this is then redistributed on an equal per capita basis to the 60% of the population with the lowest incomes. A change in distribution of this order would require considerable political support and is included primarily to study the implications for nutritional status. Under any reasonable assumptions about the evolution of the present political system, it is extremely unlikely that a redistribution of this magnitude could be achieved.

Scenario 6. This is the FAO low alternative. Its assumptions include a population growth rate of 3.5% until 1990 and then a slight fall to 3.4% for the next decade, while expenditure on private consumption would increase by 4.4% until 1985 and by 5% thereafter.

Scenario 7. The FAO high alternative assumed a similar population growth rate, but the growth rate of expenditure on private consumption is assumed to be 6.2% until 1985 and 7.2% thereafter.

The possible implications of income redistribution are considered in Section 5 using Scenarios 1, 4, and 5. In this section Scenarios 2, 3, and 4 are considered, primarily in terms of the impact on national demand. In view of the recent experience with urbanization and population growth, these scenarios would appear to be within the realm of possibility.

Note that in Scenarios 2 and 3 the average national income increases because of the relatively higher population growth rate in urban areas. Scenario 4 suggests a strong performance by the economy, as it implies that the rural sector should grow at about 3.9% per annum while the urban sector is postulated to achieve a growth rate of 7.6% per annum. This is required because of the population growth rates of 2.9% and 6.6% in the rural and urban areas respectively.

Of these three, Scenario 4 is perhaps the most interesting. It assumes that the economy progresses steadily; growth rates for population and income are in line with those envisaged in the present plan (1979–83), while the underlying assumptions are reasonably close to those in the FAO low alternative. The major difference is in the treatment of elasticities. The FAO incorporates changes in elasticities over time while the current study uses a *de facto* change in elasticities by treating urban and rural patterns separately. This is deemed necessary because of both the large average income difference (five to one) and the rather different consumption patterns.

3.7 Kenya Case Study and FAO Demand Estimates Compared

Kenya Case Study (KCS) estimates of food demand for the year 2000 are given in Tables 22, 23, and 24 for Scenarios 2, 3, and 4 respectively. For purposes of comparison the FAO "low" alternative is given alongside Scenario 2 while the "high" alternative is given alongside Scenarios 3 and 4.

In the FAO low alternative, total expenditure on private consumption grows at 4.4% until 1985 and at 5% thereafter, while for their high alternative the figures are 6.2% until 1985 and 7.2% thereafter.

TABLE 22 Estimated food consumption in the year 2000: Scenario 2[a], population 28.18 million

	Per Capita consumption (kg per annum)			Total demand (thousand tonnes)	
Commodity group	Rural	Urban	National	Scenario 2	FAO[b]
1 Maize	125.6	97.1	117.9	3324	3137
2 Millet, sorghum	19.8	–	14.8	417	553
3 Wheat	10.0	24.7	13.7	387	557
4 Other cereals (rice)	1.4	13.1	4.4	123	89
5 Potatoes	26.2	14.8	23.3	657	359
6 Cassava	30.5	3.0	23.5	663	1117
7 Sugar	10.4	20.6	12.9	365	690
8 Pulses	14.2	13.8	14.0	396	712
9 Milk	72.1	88.6	76.0	2141	1838
10 Meat and fish	15.1	33.6	19.7	556	513
11 Fats and oils	1.7	6.5	2.9	82	87
12 Vegetables	20.4	36.9	24.5	690	780

[a]Scenario 2 is with average annual per capita incomes in urban and rural sectors unchanged and a low population growth estimate.
[b]The FAO low alternative is included for comparison: see Table 20 for details.

TABLE 23 Estimated food consumption in the year 2000: Scenario 3[a], population 34.12 million.

	Per capita consumption (kg per annum)			Total demand (thousand tonnes)	
Commodity group	Rural	Urban	National	Scenario 3	FAO[b]
1 Maize	125.6	97.1	117.5	4009	2551
2 Millet, sorghum	19.0	–	14.2	484	553
3 Wheat	10.0	24.7	14.2	484	819
4 Other cereals (rice)	1.4	18.1	4.7	161	124
5 Potatoes	26.2	14.8	23.0	783	447
6 Cassava	30.5	3.0	22.7	774	1117
7 Sugar	10.4	20.6	13.3	454	1066
8 Pulses	14.2	18.8	14.1	481	798
9 Milk	72.1	88.6	76.8	2620	2273
10 Meat and fish	15.1	33.6	20.4	694	947
11 Fats and oils	1.7	6.5	3.1	105	137
12 Vegetables	20.4	36.9	25.1	856	997

[a]Scenario 3 is with average annual per capita incomes in urban and rural sectors unchanged and a high population growth estimate.
[b]The FAO high alternative is given for comparison: see Table 20 for details.

The various scenarios have significantly different outcomes, so comparisons cannot readily be made. However observations on some of the principal groups may be useful.

Maize. The Kenya Case Study estimates of demand for maize, in millions of tons, are 3.3 (low population), 4.0 (high population), and 4.2 (medium population with a 1% per capita income growth in both urban and rural sectors), while the FAO puts the figure at 3.1 for its low (income) alternative and 2.6 for its high alternative. The latter figure is lower because the FAO postulates negative income elasticity at the upper level. This is not

TABLE 24 Estimated food consumption in the year 2000: Scenario 4[a], population 31.16 million.

Commodity group	Per capita consumption (kg per annum)			Total demand (thousand tonnes)	
	Rural	Urban	National	Scenario 4	FAO[b]
1 Maize	140.9	115.5	134.1	4178	2551
2 Millets, sorghum	18.2	–	13.3	414	553
3 Wheat	12.6	31.2	17.6	550	819
4 Other cereals (rice)	1.9	17.3	6.1	189	124
5 Potatoes	34.0	16.0	29.1	908	447
6 Cassava	30.5	3.0	23.1	720	1117
7 Sugar	13.5	22.4	15.9	496	1066
8 Pulses	21.1	16.4	19.8	617	798
9 Milk	94.5	112.0	99.2	3092	2273
10 Meat and fish	19.2	42.0	25.4	790	947
11 Fats and oils	2.5	7.6	3.9	121	137
12 Vegetables	25.1	41.2	29.4	917	997

[a]Scenario 4 is with average annual per capita incomes increasing by 1% per annum in urban and rural sectors and a medium population growth rate.
[b]The FAO high alternative is given for comparison: see Table 20 for details.

supported by calculations made on data available from the various household studies, which cover all except the top few per cent. A figure of four million tonnes seems reasonable.

Millet and sorghum. As urbanization progresses, average national per capita consumption levels for millet and sorghum will fall (Scenarios 2 and 3). This effect will be reinforced by higher per capita income levels for middle and upper income groups (Scenario 4). The FAO estimates consumption at 550 thousand tonnes, around 50 to 150 thousand tonnes above Kenya Case Study estimates. Demand other than for direct consumption may contribute up to 100 thousand tonnes so that a compromise figure of 500 thousand tonnes may be reasonable.

Wheat. Consumption is particularly sensitive to income changes and urbanization. Thus the FAO estimates 557 thousand and 819 thousand tonnes for its low and high options while Scenarios 2, 3, and 4 give 387, 484, and 550 thousand tonnes respectively. In view of the sharp urban–rural difference in consumption, the FAO high estimate may have overestimated the effect of expenditure change in rural areas. Around 550 thousand tonnes seems a reasonable compromise.

Other cereals (rice). Here FAO estimates are on the low side, probably owing to a low base estimate. Around 160–180 thousand tonnes seems reasonable.

Potatoes and cassava. There are some differences between the separate estimates for potatoes, sweet potatoes, and cassava. However, when these are combined the demand estimates fall in the range 1.3–1.6 million tonnes.

Sugar. FAO estimates of 690 (low) and 1066 (high) thousand tonnes appear to be considerably higher than Kenya Case Study estimates, which range from 365 to 496 thousand tonnes. Much of the difference may be attributed to the higher elasticity estimates (around 1.0) used by the FAO. While these seem to be in line with much international experience, Kenyan data yield a much lower value for the elasticity for urban areas (0.32), where most of the additional income is expected to be generated. A figure of 500–600 thousand tonnes seems reasonable.

Pulses. Kenya Case Study estimates range from 400 to 600 thousand tonnes, while FAO estimates are about 200 thousand tonnes higher. Since Kenya Case Study estimates are based on Integrated Rural Survey 1, they include little other than beans. The FAO estimate is better for total pulse production.

Milk. Kenya Case Study estimates range from 2.1 to 3.1 million tonnes, while the FAO places demand in the 1.8–2.3 million tonne range. The FAO apparently underestimated the base year demand level. This, together with demand reinforcement by the school milk program, suggests that the higher Kenya Case Study figure may be more realistic.

Meat and fish. Demand will increase rapidly owing to higher per capita income levels and increased urbanization. Both sets of estimates overlap, suggesting that demand is likely to be in the range of 600–800 thousand tonnes.

Fats and oils. Both sets of estimates overlap, and the likely demand range should be 90–120 thousand tonnes depending on the growth rates for population and income.

Vegetables. The estimates overlap and suggest that demand should be in the 700–900 thousand tonne range. Again, this will depend on population and income growth rates.

Summary

The level and composition of food demand in Kenya by the year 2000 will depend on many factors, but primarily on the size of the population, the growth of income, and the price structure. Maize will still dominate the food crops. With medium population growth and 1% annual per capita growth in income (Scenario 4), the demand for maize in 2000 is estimated at 4.2 million tonnes. For this scenario, which seems closest to the aims of current planning, sharp increases in demand can be expected for wheat, rice, meat, and dairy products. If the income gain fails to materialize, demand for these four commodity groups would not rise as much, but the demand for maize would still be around 4 million tonnes.

In Section 4 the production side is analyzed and then both sides of the equation are considered in Section 5.

4 AGRICULTURAL PRODUCTION

4.1 Introduction

Agricultural production in Kenya is directed toward three primary objectives:

- satisfying domestic food needs
- supplying domestic commercial and industrial needs
- making a substantial contribution to the nation's balance of payments through exports

In Section 3 we discussed demand, and it was indicated that the average Kenyan diet is based on cereals, primarily maize, meat (mostly beef), and dairy products. Most of these needs are met by domestic production. In the second category of needs are cotton, pyrethrum, sisal, and wattle, while coffee and tea account for a major share in exports.

To achieve these objectives there are resources of varying quantity and quality – these include manpower, land, and various inputs, including energy, seed, fertilizer, and herbicides. The government then chooses an appropriate policy mix to try to ensure that resources are used as efficiently as possible to achieve the desired objectives. Invariably, optimum economic solutions are tempered by the sociopolitical reality and the historical evolution of the current structure. Within Kenya there is a great variety of modes of production, varying from large plantation operations to smallholder subsistence farming.

The policy maker must also be sensitive to the various noneconomic forces. In Kenya there is a very strong desire among most of the population to own a *shamba* (a piece of land). This supersedes in many instances any economically rational evaluation of the viability of certain smallholdings.

In Section 4 the ecological setting is first considered. Recent and past trends are considered for the various commodities. This is followed by a discussion of various policy instruments together with distribution and marketing issues.

4.2 The Ecological Setting of Kenya's Agricultural Sector

The most useful classification of land potential in Kenya was devised by Pratt *et al.* (1966). Their classification in terms of ecological land units derived from combinations of climate, soil, and topography equated with vegetation types is given in Table 25. Six broad ecological zones are distinguished, as follows.

Zone I comprises about 80,000 hectares, or about 0.1% of Kenya's land area, at high altitudes above the tree line. This is mostly barren land except for scattered moorland or grassland vegetation. Land use is limited to water catchment and tourism.

Zone II comprises Kenya's high potential agricultural area. It extends to some 5.3 million hectares, or 9% of Kenya's land area, and it embraces the bulk of Kenya's forests, both

TABLE 25 Ecoclimatic land potential: classification of agricultural land in Kenya.

Zone	Current land use	Area (thousand hectares)	Percentage of total
I	Water catchment and tourism	80	0.1
II	Coffee, tea, pyrethrum, cotton, and livestock	5300	9.3
III	Maize, wheat, barley, cotton, groundnuts, pulses oilseeds, and livestock	5300	9.3
IV	Subsistence crop farming, livestock, sisal, and wildlife	5300	9.3
V	Wildlife and livestock	30,000	52.5
VI	Livestock	11,200	19.6
TOTAL		57,180	100.0

SOURCE: Based on Pratt *el al.* (1966).

indigenous and exotic. The vegetation is forest and its derivatives. The agricultural potential of this land is very high, especially in the highland areas. Coffee, tea, and pyrethrum are important cash crops at high altitudes, while cotton can yield good results at lower elevations. Land in this zone is also suitable for intensive livestock farming.

Zone III is a medium potential agricultural area. It also covers some 53 million hectares, or 9% of Kenya's land area. Most of the large-scale mixed farming areas are in this zone, in which hybrid maize*, wheat, and barley are the most important cash crops. The small-scale farming comprises maize (hybrid and local varieties), cotton, groundnuts, pulses, and oilseeds. Cashew and coconuts are also grown in this zone. Livestock does well and carrying capacities are high.

Zone IV has a total area again of about 5.3 million hectares, or 9% of the land area. This zone has only a marginal potential for agriculture. Subsistence crop farming and animal production are the important occupations of the smallholder farmers in this zone. Sisal plantations are located here, and it is also the area in which most of Kenya's game is found.

Zone V covers just over 30 million hectares, or 52% of Kenya's land area. It is an area of moderate rangeland development potential. Wildlife is important in many areas, but this area has also been the focus of many of the present and proposed livestock development programs.

Zone VI extends to approximately 11.2 million hectares, or 20% of the total land area, and comprises most of northern Kenya. Rainfall is sparse and erratic. Vegetation is annual grass species which spring after the rains. Livestock is kept by nomadic pastoral people who inhabit this zone. There is a more limited development program for this zone.

This classification gives a general indication of the agricultural potential. It is also in line with recent estimates by government sources for land potential. These are given by province in Table 26. Whether this potential is realized or not depends on many factors. It should be noted that a large part of Kenya is not good farming land. It is on this land that most of Kenya's 14 million population is located. The remaining 80% of the land cannot support food production without irrigation and other inputs. Current investment levels and technology in the dry low potential areas can only support extensive livestock production and pastoral nomadism. However, even a pessimistic estimate of high potential agricultural land is about 6 million hectares. This should be more than adequate to support the current population.

4.3 Agricultural Production

4.3.1 Current Situation

The general composition of agricultural production is shown in table 27, which is taken from the chapter on agriculture in the Development Plan (1979–83). This gives the estimated value of production for crops and livestock. The composition could also be given in terms of employment or land use, which would give a different emphasis.

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*Maize is both a cash crop and a subsistence crop.

TABLE 26 Land potential: provincial and national land areas (1978).

Land type	Land area (thousand hectares) by province						
	Coast	Eastern	Central	Rift Valley	Nyanza	Western	TOTAL
Total area	8303.0	15,576.0	1330.3	16,845.4	1260.5	828.1	44,143.3
High potential	581.8	334.0	604.4	2193.7	961.3	660.2	5335.4
Medium potential	1238.7	819.5	168.3	922.2	163.9	3.4	3316.0
Low potential[a]	6148.5	12,860.1	438.4	12,007.4	9.2	81.8	31,583.0
Other[b]	830.3	1561.5	132.9	1688.2	126.0	82.7	4377.5
Cropped areas[c]	240.9	558.6	307.9	503.0	267.7	304.2	2182.3
Cropped area as a percentage of high and medium potential land	18	34	40	16	24	46	25

[a]Includes marginal, range, and desert areas.
[b]An average of 10% was deducted from high, medium, and low potential land to represent land not available for agricultural production (roads, infrastructure, rocks, and swamps).
[c]Long rains only.
SOURCE: Otieno *et al.* (November 1978).

TABLE 27 Total value of production of agricultural commodities (in thousand Kenya pounds (1976)).

Commodity group	1976 actual	1978 estimate	1983 target	Average annual rates of growth 1976–78 per cent	1978–83 per cent
Food crops					
Maize[a,b]	94,486	101,188	120,224	3.5	3.5
Wheat	11,248	11,429	12,030	1.0	1.0
Rice (paddy)	2670	3217	4449	7.6	6.7
Sorghum, millets, etc.	14,196	15,372	19,614	4.7	5.0
Pulses	22,946	24,994	32,340	5.0	5.5
Potatoes	20,400	22,200	27,400	4.3	4.3
Other starchy roots	11,900	12,776	15,241	3.6	3.6
Fruit and vegetables	8346	9399	14,469	8.2	9.0
Bananas and plantains	11,600	12,650	16,550	5.2	5.5
TOTAL	197,792	213,225	262,317	4.1	4.3
Industrial crops					
Oilseeds and nuts	3354	3659	5286	6.7	7.6
Sugarcane	8678	8925	17,850	10.9	14.9
Seed cotton	1669	1773	3546	11.4	14.9
Tobacco	237	444	1096	24.5	19.8
Barley	2644	2805	6042	12.5	16.6
TOTAL	16,582	17,606	33,820	10.7	14.0
Export crops					
Coffee[c]	98,792	117,315	138,309	4.9	3.4
Tea	32,763	45,975	57,601	8.4	4.6
Sisal	3856	3739	4674	2.8	4.6
Pineapples	1314	1823	3562	15.3	14.3

TABLE 27 *Continued.*

Commodity group	1976 actual	1978 estimate	1983 target	Average annual rates of growth 1976–78 per cent	1978–83 per cent
Pyrethrum	4347	4347	7763	8.6	12.3
Cashew nuts	1159	1546	2318	10.4	8.5
Wattle	515	515	552	1.0	1.0
TOTAL	142,746	175,260	214,779	6.0	4.2
Livestock products[d]					
Milk (dairy products)	60,900	67,515	86,100	5.1	5.0
Beef cattle	34,198	33,223	39,770	2.2	3.7
Sheep and goats	17,050	17,574	21,509	3.4	4.1
Pigs	1048	1114	1441	4.7	5.3
Poultry meat	8890	9843	12,383	4.9	4.7
Eggs	7350	8050	10,500	5.2	5.5
TOTAL	129,436	137,319	171,703	4.1	4.6
TOTAL AGRICULTURE	486,556	543,410	682,619	5.0	4.7

[a]The former major crops are maize, wheat, rice, sugarcane, seed cotton, tobacco, barley, coffee, tea, sisal, pineapples, pyrethrum, and cashew nuts. All estimates are of total production.
[b]The production data presented for the majority of these minor crops and livestock products are much less accurate than those for the "major crops" and are derived from various sources.
[c]Based on the assumptions that over the plan period 1976 coffee price levels will be maintained, and fertilizer application rates will double.
[d]Estimates without a reliable statistical base.
SOURCE: Development Plan 1979–83.

The three principal components are food crops, export crops, and livestock. Industrial crops do not currently command a very large share.

4.3.2 Future Prospects for Production and Employment

Kenya is faced with an acute shortage of high potential land together with one of the highest population growth rates in the world – about 4% per annum. However, the average output per hectare for many crops, such as maize, is relatively low by world standards. A number of authors (Ruthenberg 1978) have suggested that the major strategy be that of using land intensively.

4.3.2.1 Land Use Intensification

Most of the potential for output and employment is in the high and medium potential areas, which are also areas of high population density, especially Nyanza Province and Western Province. Rural poverty is also concentrated in these two provinces, which account for 60.5% of the total poor in the country (Crawford and Thorbecke 1978).

Three major elements of land use intensification are usually identified as*:

*After Ruthenberg, 1978. The first part of the Crawford and Thorbecke paper frequently draws on Ruthenberg's paper.

- higher yields per hectare of crop
- increasing the hectarage under intensive crops, i.e. under crops with a high value added of output per hectare and a high employment content
- multiple cropping, i.e. the interplanting of the main crop with a secondary, or the planting of two crops per annum

However, if land use intensification is to be economic, then various measures have to be deployed. These include the provision of agricultural innovations through research and extension, i.e. better varieties, tools, breeds, etc.; the provision of inputs, particularly chemical inputs; and the adaptation of cropping patterns and types of livestock production. The provision of research and extension by the government will be discussed at length in Section 4.6 of this report.

Changing cropping patterns on existing land can have a substantial impact on production and employment. Tables 28 and 29 show the employment estimates for different crops on small and large farms. It is evident that there is wide range in the employment and production potential of different crops.

Table 28 shows for example that tea provides four times as much employment as maize per hectare. Tables 28 and 29 show a more dramatic picture, where smallholder

TABLE 28 Estimated crop hectarage, livestock, and employment in the small farm sector in Kenya.

Crop	Hectares	Hours per hectare	Total hours (thousands)
1. Cereals, pure stands			
Local maize	224,600	800	179,680
Hybrid maize	258,200	900	232,380
Finger millet	30,500	1000	30,500
Sorghum	16,800	300	13,440
Other cereals	18,500	700	12,950
TOTAL			468,950
2. Cereals, mixed stands			
Local maize; beans, sweet potatoes	834,000[a]	800	667,200
Hybrid maize, other	242,600	900	218,340
Sorghum, grain legumes, etc.	97,600[a]	700	68,320
TOTAL			953,860
3. Pulses, pure stands			
Beans	49,900	400	19,960
Cow peas	11,700	300	3,510
Pigeon peas	100	400	40
Field peas	4100	600	2460
Groundnuts	3500	800	2800
Other	1100	300	330
TOTAL			29,100
4. Root crops, pure stands			
English potatoes	48,900	1100	53,790
Sweet potatoes	10,900	1000	10,900
Cassava	41,200	1100	45,320
Other	17,700	1000	17,700

TABLE 28 *Continued.*

Crop	Hectares	Hours per hectare	Total hours (thousands)
5. Fruit, vegetables, oilseeds, pure stands			
Bananas	19,600	1100	21,560
Other fruits	1200	1000	1200
Vegetables	4000	2000	5000
Oilseeds	13,000	800	10,400
6. Industrial crops, pure stands			
Sugarcane	55,000	1500	82,500
Pyrethrum	22,400	2800	62,720
Cotton	25,000	1500	37,500
Other	2600	1000	2600
7. Cotton, mixed stands	45,100	1000	45,100
8. Permanent crops, pure stands			
Coffee	92,000[b]	2500	230,000
Tea	59,000[c]	3200	188,800
Coconuts	2000	200	400
Cashew	5500	200	1100
Other	23,100	500	11,550
9. Permanent crops, mixed stands	19,300	2100	40,530
Coffee, bananas, maize	19,300	2100	40,530
Coconut, cassava, maize	49,300	1200	59,160
Cashew, cassava, maize	48,000	1200	57,600
Subtotal	2,397,300		2,440,340
Minus area doublecropped (15%)	−395,595		−366,051
Total crop hectarage	2,037,700		2,074,289[e]
Plus pastures, etc.	1,420,300[d]		
TOTAL SMALL FARM HECTARAGE	3,458,000		2,074,289[f]

Livestock type	Number of animals	Hours per head per year	Total hours (thousands)
Dairy cows (improved)	611,000[g]	400	244,400
Calves, heifers (improved)	661,448[g,n]	250	165,362
Bulls, steers, oxen (improved)	185,552[g,n]	200	37,110
Unimproved cows	1,942,000[g]	300	582,600
Unimproved other cattle	3,435,000[g]	200	687,000
Sheep and goats	6,522,000	25	163,050
TOTAL			1,879,522[h]

Total employment	Hours (thousands)	Percent of total	
Total crops (less doublecropping)	2,074,289	46.4	
Food crops[i]	1,358,823	66.0	Percentage of total crops
Industrial crops[j]	204,697	9.9	
Plantation crops[k]	500,769	24.1	

TABLE 28 *Continued.*

Total employment	Hours (thousands)	Percent of total
Total livestock	1,879,522.4	42.0
General farm work[l]	517,891	11.6
GRAND TOTAL	4,471,702.4[m]	

[a]Residual, after subtracting pasture and all other crop area from total holding area: 3.458 – 1.435 – 1.466.4 (million hectares) = 931,600. Table 9 in Integrated Rural Survey 1 (IRS1) gives the total mixed local maize area as 970,000 hectares and that for mixed sorghum as 189,600. These undoubtedly involve overestimation and double counting.
[b]The Coffee Board gives 86,389 × 2,500 = 215,972,500.
[c]The Tea Board gives 65,960 × 3200 = 211,072,000. With the Coffee Board figure of footnote *b*, this makes 427,044,500 versus 418,800,000 above: a difference of 2%.
[d]Pasture areas are estimated by province as follows (in hectares): West, 325,525; Rift Valley, 146,758; Nyanza, 271,574; East, 214,384; Coast, 1000; Central, 461,059; TOTAL, 1,420,300.
[e]Average 1018 hours per hectare of crops.
[f]89% of norm by IRS1: 1579 hours × 1.48 million.
[g]Ruthenberg breakdown of the average number of cattle given in IRS1 1974 and 1975.
[h]Average hours per head of livestock times number of holdings: 1368 × 1.48 million = 2,029,321,296; the figure given is 93% of this.
[i]Categories 1–5 minus oilseeds.
[j]Categories 6 and 7 plus oilseeds.
[k]Categories 8 and 9.
[l]Approximately 350 hours × 1.48 million holdings.
[m]Total ÷ 2000 hours per man year = 2,235,851 man years; total ÷ 2400 hours per man year = 1,863,209; total – general = 3,953,811,400, which is 1,976,906 man years at 2000 hours per man year and 1,647,421 at 2400 hours per man year.
[n]Proportional split of total 847,000.
SOURCE: Integrated Rural Survey 1, 1974–75; Crawford and Thorbecke (1978) Chapter 3.

TABLE 29 Estimated crop hectarage and employment in large-scale farming in Kenya in 1976.

Crop	Hectares[a]	Hours per hectare[b]	Total hours
1. Large mixed farm crops			
Wheat	86,595	70	6,061,650
Barley	13,141	70	919,870
Oats	4153	70	290,710
Maize	74,317	350	26,010,950
Other grains	1164	70	81,480
Sunflower	3890	120	466,800
Pyrethrum	3036	2000	6,072,000
Root crops and vegetables	3527	3000	10,581,000
Temporary fodder crops	8500	70	595,000
Other temporary crops	115,596	200	23,119,200
Other crops	265	200	53,000
TOTAL	314,184		74,251,660
Squatter maize	300,000[b]	800	240,000,000
2. Plantation crops			
Tea	25,301	4300	108,794,300
Coffee	29,841	2800	83,554,800
Sugarcane	30,098	1000	30,098,000
Sisal	76,994	300	23,098,200
Pineapple	5033	1500	7,549,500

TABLE 29 *Continued.*

Crop	Hectares[a]	Hours per hectare[b]	Total hours
Wattle	11,779	200	2,355,800
Coconuts	1636	200	327,200
Cashew	1121	200	224,200
Other	3063	500	1,531,500
TOTAL			257,533,500

	Number of animals	Hours per head per year	Total hours
3. Livestock			
Dairy cows	175,100	200	35,020,000
Heifers	95,800	20	1,916,000
Calves, bulls, etc.	19,200	24	460,800
Beef cattle	456,500	20	9,130,000
Sheep	325,700	2	651,400
Pigs	18,100	2	36,200
TOTAL			47,214,400

		Percentage of total
4. Summary		
Total mixed farm crop hours	74,251,660	12.0
Total plantation crop hours	257,533,500	41.6
Total livestock hours	47,214,400	7.6
Squatter maize	240,000,000	38.8
Subtotal	618,999,560	100.0
Overhead labor (20%)	123,799,912	
GRAND TOTAL	742,799,472[c]	

[a]Statistical Abstract (1977) Table 97(e).
[b]Estimate based on Hunting (1977).
[c]Equivalent to 371,400 employed at 2000 man hours per year, 309,500 at 2400 man hours per year.
SOURCE: Crawford and Thorbecke (1978) Chapter 3.

potato production uses more than 15 times as much and smallholder pyrethrum uses 40 times as much labor per hectare as large-farm wheat production*. The data in these tables further indicate that except for horticultural crops, such as bananas, flowers, vegetables, and other fruits, the diversification away from cash crops such as coffee, tea, cotton, pyrethrum, and sugarcane does not offer increased potential for employment. There is also the problem that concentration on cash crop production increases the dependency on erratic world markets and brings an element of economic instability into the development of the country (Ruthenberg 1978).

If we were concerned only with direct employment, the national cropping patterns should favor coffee, tea, pyrethrum, sisal, and sugarcane. The creation of employment is of great concern to the government.

*Tidrick (1979) has noted that it is difficult to distinguish the effects of changes in cropping patterns and changes in farm size.

Although it would appear from Tables 28 and 29 that the shifting of cropping patterns can offer a substantial increase in output and employment, one should not be misled into thinking that changes in cropping patterns are a panacea for all production and employment problems. There are limits to the operation of these changes, including land quality, product demand, the need to fit crops into the farming system, and inadequate supporting services and consumption patterns. For example, tea has on average a higher value added per hectare than maize, but there will be many areas in which maize will have a higher return per hectare than tea owing to land quality.

International agreements limit the expansion of such crops as coffee, pyrethrum, and sisal. Product demand is thus a limit to changing cropping patterns. Changing cropping patterns can also be limited by the need to fit crops into the farming system. The labor profile in a farming system is critical because peak season labor requirements may constrain production of some high value, labor-intensive crops. This means that comparison of the annual labor requirements of crops can be very misleading.

The supporting services available to the farmers can be a further limit to changing cropping patterns. A well-known example in Kenya is potato production, which is usually limited by inadequate storage and marketing facilities. Yet Table 28 indicates that potato production has a very high employment component.

The final limit to changing cropping patterns is consumption patterns. Here wheat is a good example: producers have followed the dictates of consumers. Demand for bread has increased in Kenya at a rate of 6–8% per annum. The production of wheat continues to be promoted despite the fact that the income per hectare of high potential land is relatively low. The employment content is negligible, as indicated in Table 29. Its foreign exchange requirement is very high since it requires high inputs of imported machinery. Here it can only be hoped that high wheat prices as well as the development of triticale will change consumption patterns in the long term. An enlightened pricing policy can have a large impact on cropping patterns.

Nevertheless, despite the above limitations, there is still considerable scope for increasing output and employment by changing cropping patterns. Changes in cropping patterns in Central Province between 1963 and 1974 increased labor demand by 28% or 2.3% per annum (Collier and Lal 1978). This mainly involved the expansion of tea, coffee, and hybrid maize. Much of the hybrid maize expansion replaced traditional varieties. In the future, similar or higher gains for changing cropping patterns should be experienced throughout the economy. The main requirement is for policy and institutional support: pricing policy, marketing and transport facilities, credit arrangements, improved input distribution, and research into ways to ease the constraints that prevent the adoption of high value, labor-intensive crops (Tidrick 1979).

4.3.3 Increased Yields

Yield increases are an important source of output growth; the average yields in Kenya are low. The average yield of maize for example is about one tonne per hectare, compared with 1.95 tonnes in Mexico and 5.4 tonnes in the US (Financial Times 1980).

Increased yields of labor-intensive crops such as tea, coffee, sugarcane, pyrethrum, and cotton can generate significant employment, especially in harvesting. However, doubling or increasing the yield substantially will not be automatic. Ruthenberg (1978) contends that yields may have stabilized or actually fallen in recent years, especially among smallholders. He attributes this to the low use of fertilizer in smallholder agriculture. Fertilizer use in Kenya is very low in comparison with other tropical countries short of land, and smallholders accounted for less than one third of its consumption in 1976–77.

If yields are to be increased substantially, the current trend in fertilizer use by small-farmers must be reversed. This will hinge upon government policy and institutional support. The issue here is not farmers' technical capability of raising yields using fertilizers, but rather the profitability of using fertilizer, its availability at the correct time and at reasonable distances from farmers' fields, and credit facilities.

There is ample evidence that, given the incentive, smallholders can respond to fertilizer use. The Kenya Tea Development Authority (KTDA) is a good example: fertilizer use in tea growing has been promoted with much success. The KTDA provides fertilizer to farmers close to their fields and provides credit, and farmers have fertilizer when they need it. The KTDA can do this because they deduct the fertilizer cost at source.

The general marketing of fertilizers to small-farmers has been the factor limiting fertilizer use: farmers do not get fertilizer at the correct time and dealers do not extend credit. The dealers are not localized as in the case of the KTDA; farmers have to travel long distances and transport costs are prohibitive.

The study by Mwangi (1978) in Kenya's Central Province indicated that farmers traveled on average eight miles to buy fertilizers. Of all farmers using fertilizers, 42% transported their fertilizer by public transport (matatu) while 38% transported their fertilizer on foot. The average return fare for farmers was KSh2.50 and the average transport cost for a 50kg load was KSh1.45. These costs raised the price of fertilizer substantially, not including the opportunity cost of the time spent in going to buy it. The same study found that 59% of the farmers were not using fertilizers at all owing to lack of funds, while the same lack of funds made 68% of farmers use inadequate or subeconomic amounts at prevailing prices.

Thus for yields to be increased conditions must be created that are conducive to the use of fertilizers by small-farmers*. The areas that need special attention are price policy and institutional support, especially marketing, credit, and extension.

4.4 Land Redistribution

In this section the redistribution of large holdings is considered as another way of increasing the intensity of land use. The burning issue of land policy will be discussed later in this section in connection with government policy and institutional support for agriculture.

Tidrick (1979) has observed that few would dispute that land redistribution could increase agricultural employment, but the effect on output is much more controversial. However, after analyzing the available data, especially from Integrated Rural Survey 1, he has concluded that small farms have on average both higher employment and higher output per hectare than large farms using land of comparable quality.

*There are also other technical inputs that increase yields, such as pesticides and improved irrigation where feasible.

Table 30 shows the current distribution of land holdings and employment. For example, assume as Tidrick (1979) did that there are about 585,000 hectares of large mixed farms not already subdivided plus gap farms (1 million hectares) that could be subdivided, and further that subdivided holdings would provide 0.64 man years of employment per hectare (the average for all smallholdings in 1974–75) compared with an average of about 0.09 man years employment per hectare on large mixed farms and gap farms. Under these assumptions, land redistribution would provide an additional 0.55 man years of

TABLE 30 Distribution of land and employment.

	Area (thousand hectares)	Employment (per cent)
Pastoralists, landless, and squatters	–	12.0
Smallholders	3500	(74.6)
Food crops		26.8
Livestock		29.0
Other		18.8
Irrigation schemes	9	0.2
Gap farms[a]	1000	2.5
Large farms	2500	
Mixed farms	900	2.3
Plantations	400	4.7
Ranches	1200	–
Squatters		3.7
TOTAL	7009	100.0

[a]Gap farms are those not covered by the Integrated Rural Survey or the Large Farm Survey and are considered to be 20–50 hectares in size.
SOURCE: Crawford and Thorbecke (1978); Development Plan 1979–83, Statistical Abstract.

employment per hectare on 1,585,000 hectares, or approximately 870,000 extra jobs. Thus from this one example it is clear that land redistribution would go a long way toward alleviating unemployment. In fact Tidrick (1979), in further calculations using other assumptions, shows that land redistribution could create approximately 4 million extra jobs. However, he places a caveat on this conclusion, since these calculations of the employment and output potential of redistribution require strong assumptions about land quality on large and gap farms and about the political feasibility of redistribution.

The discussion so far of the potential for increasing output and employment has been concentrated on the existing land area under cultivation. We now turn to exploring the possibilities of increasing output and employment through increasing the supply of agricultural land, which can be achieved through irrigation, drainage, or conversion of forests and pastures.

4.5 Increased Supply of Agricultural Land

4.5.1 Irrigation and Drainage

Irrigation and drainage afford substantial potential for the expansion of Kenya's cultivable land in the medium and long term. The potential area for irrigation is estimated at about 600,000 hectares, while the country's potential area for reclamation through drainage is also as much as 600,000 hectares. At present less than 5% of irrigation and 1% of drainage potential has been developed (Toskoz 1979).

Toskoz (1979) has estimated that the development of 200,000 hectares of irrigation and 200,000 hectares of drainage, covering only one third of Kenya's potential, would cost K£1400 million. This would in turn generate an equivalent full-time employment potential of nearly 1.3 million people compared with the expected 7 million increase in the labor force between 1979 and 2003.

Irrigation could also provide substantial production benefits. The projected value added under the Bura project is around K£450 per hectare (in 1979 prices). At this rate the value added would be K£270 million if the potential area is 600,000 hectares.

However, the employment and production potential of irrigation must be treated with caution for two basic reasons. First, irrigation is enormously expensive. The latest cost estimate of the 6700 hectare Bura scheme is K£63 million, or about K£9400 per hectare. (This scheme is particularly expensive, though, because of high infrastructure expenditures that would not all be required in a less remote area.)

The Ministry of Agriculture estimates that the cost of irrigation development, including additional infrastructure costs but excluding much of the cost of dam construction, would range between K£3000–6000 per hectare. Thus the development cost of 600,000 hectares would be in the range K£1.8–3.6 billion. This is a big investment by the standards of any developing country.

The second reason for calling for caution in considering the potential of irrigation development is the technical and economic problems that have arisen in some irrigation schemes. Although the Mwea scheme is generally recognized as highly successful, other irrigation schemes in Kenya have been less so. Some of these schemes were established with other objectives; for example, the Mwea scheme was used to "rehabilitate" Mau Mau detainees. Tidrick (1979) notes that Perkerra has been regarded as a disaster while the latest cost estimates for the large Bura scheme have lowered the economic rate of return to 9%, which makes it a marginal project and raises questions about the economic viability of large-scale irrigation.

In the light of all this, the development of irrigation as a major source of production and employment is of dubious potential.

The government's strategy for irrigation seems highly appropriate under the circumstances: that is, to proceed cautiously with presently planned large-scale irrigation schemes, to make no new large-scale commitments, and to promote small-scale and private irrigation development (Tidrick 1979). Nevertheless, this alone could make a significant contribution.

4.5.2 Drainage

For drainage, unlike irrigation, there has been little investment. However, in the fourth Five Year Development Plan (1979–83) there is a commitment to drain about 3000 hectares in Coast Province in order to produce wet rice (Government of Kenya 1979).

Ruthenberg (1978) has been the staunchest advocate of drainage and valley bottom development in the Ministry of Agriculture. He claims the following advantages in increasing the supply of land through drainage.

- Some of the most fertile land is found in poorly drained valley bottoms. This land would respond well to the application of fertilizer and would have a lower risk of drought.
- Drained land could support very labor-intensive cropping and most of the potential products (rice, vegetables, and cotton) would find a ready market in Kenya.
- Drainage shows a high rate of return and results in permanent improvement.
- Valley bottom development is closely connected with resource conservation because it implies water control, land leveling, and protection of catchment areas.

Ruthenberg estimates that there are up to 1 million hectares of high and medium potential land with impeded drainage. Most of this land is in Western Kenya, but there are also extensive areas in Coast Province and Rift Valley Province. In Central Province drainage is of minor importance.

The cost of drainage is only K£400 per hectare, compared with over K£3000 per hectare for irrigation.

The advantages of drainage development are thus that is has a high employment content since it is a labor-intensive undertaking, it has a higher return of capital investments than irrigation, and it is likely to be more economic. One problem here is that Kenya has little experience in drainage and valley bottom development.

There are substantial externalities involved in valley bottom farming. Investment in drainage by one farmer will benefit neighboring farms, but it will be unproductive if neighboring farms do not also invest in and maintain their part of the drainage system. This implies that if drainage development is to be effective, the government would have to devise new institutions and procedures to coordinate planning. Because of the externalities involved in drainage maintenance, participation in drainage development cannot be voluntary. The government would also have to devise special arrangements to ensure equitable sharing of the costs and benefits of drainage development.

4.5.3 Clearing of Forest

Clearing large areas of forest is another possibility for increasing the supply of arable land for crop development. This is a controversial proposal because of its unknown ecological effects, which would depend very much on where and how the cutting was done. Moreover, memories are still bitter about the indiscriminate cutting of trees by a few influential Kenyans for the lucrative charcoal market in the Middle East.

From an economic point of view, proponents of this idea argue that tea and other crops, such as bananas, can provide an adequate watershed, while providing a large increase in employment and value added. From Tables 28 and 29, it is suggested that a hectare of tea provides about 2 man years of employment or about K£500 gross output (at 1976 prices). If, as claimed, 400,000 hectares of high potential land could be safely cleared, it would provide 800,000 jobs and K£200 million gross output. In practice this would take a long time and a detailed evaluation should be made of the effect on tea prices. The total area planted to tea in Kenya in 1976 was 66,000 hectares. Furthermore, as long as there are conflicting uses of forest, such as for harboring wildlife, or for tourism, and unknown environmental effects in replacing forests with permanent crops, this idea is bound to generate animated discussion in the near future.

4.5.4 Dryland Farming

Four fifths of Kenya's land area lies in the semiarid and arid agroecological zones IV, V, and VI. The marginal areas support 25% of the total human population and 50% of the livestock in Kenya. Much of the area is devoted solely to pastoralism, but there is increasing migration from densely populated high potential areas to sparsely populated marginal areas, particularly in Zone IV.

These areas have no potential for generating substantial output and employment. The development strategy in the marginal areas should be to try to raise the living standards of the existing population rather than to try to expand production through immigration.

At this stage we should also turn to a consideration of animal production. Beef production requires large areas of land, which are no longer readily available. This would call for a shift towards zero grazing, which is already being adopted in the high potential areas, or alternatively a combined effort whereby cattle could be reared, if not fattened, on rangeland. The alternative is to shift consumption to milk, sheep, and goats. Milk production on small farms generates a high income per hectare and a high employment content but currently there are significant marketing problems. The quick reproduction patterns of sheep and goats lend themselves to the use of crop byproducts in small farm units.

Table 31 shows the potential impact on production and employment of the possibilities that have been discussed in Section 4.

TABLE 31 Production and employment potential from alternative sources.

	Maximum estimate		Moderate estimate	
Source	Output (million K£)	Employment (thousands)	Output (million K£)	Employment (thousands)
Irrigation	225	2000	90	400
Drainage	300	2000	150	1000
Clearing of forest	200	800	6	40
Dryland farming	Negligible	Negligible		
Changes in cropping patterns[a]	200	2750	125	1750
Increased yields	600	1000	450	750
Land redistribution[a]	600	3800	50	870
TOTAL POTENTIAL INCREASE[b]	1925	9600	821	3940
Increase required by 2000	1000	3800	1000	3800

[a]Changes in cropping patterns and land redistribution are not additive.
[b]The total excludes the smaller of the changes in cropping patterns or land redistribution. Excluded from the total are changes due to increased yields from the application of technology not yet developed and intensification due to the subdivision of existing smallholdings.
SOURCE: Tidrick (1979).

In conclusion to this section, we should reiterate two points that were made by Tidrick (1979) concerning prospects for employment and production growth in agriculture.

Agricultural development will require major investments to expand land area, difficult political decisions to redistribute land, and careful attention to policy and the development of supporting institutions. Changes in government policy will be essential if the slowing of agricultural growth is to be reversed. Secondly, although there are no technical problems in the medium term in expanding agricultural output and employment, if population growth does not slow down dramatically by the end of the century, the provision of adequate employment opportunities and indeed overall development will become intractable problems. The experiences of other countries suggest that a more equitable distribution of the benefits of economic growth may be essential to bringing down the rate of population growth.

4.6 Government Policies and Institutional Support

The targets of output as outlined in the Kenya Case Study can only be expected to be met through the promotion of smallholder farming. In this section of the report we shall turn our attention to the policies required for smallholder development. These policies include pricing, marketing, research, extension, credit, and land policy.

4.6.1 Pricing Policy

Prices of export crops are largely determined by world prices, as Kenya has little market power. The one exception is pyrethrum.

The price support system has played a useful role in the past in encouraging innovation by removing the risk of price fluctuations for important crops. Kenyan farmers have become exceptionally price responsive and very aware of market opportunities. This implies low supply elasticities and hence a low marginal cost to government. The government should thus seriously review its role in price support and give some consideration to the desirability of less government intervention.

Fixed price support may be justified in cases where the government is trying to expand production of a new or neglected crop, but in general farmers and consumers would be better off if government marketing boards played a more restricted role. The boards should set minimum and maximum support prices for maize and other key crops, but otherwise should permit full private sector compensation (Tidrick 1979).

The price policy has an impact on income distribution. Food price controls frequently benefit middle- and upper-income urban groups at the expense of lower-income rural producers. Cases in point are the price controls on meat and maize, which transfer income from low-income herdsmen and farmers to the benefit of middle- and upper-income urban dwellers.

It should be noted, however, that the scope for price policies is limited owing to the dependence on exports and the limited purchasing power of the internal market.

4.6.2 Marketing Policy

In Kenya the tradition of centralized marketing has been the order of the day. The government not only provides marketing organizations for many crops, but frequently forbids trade through unauthorized channels. Marketing policy is tied up with pricing policy. There is a preannounced support price for the major grain crops and single-channel marketing is the principal way the government seeks to make its support price effective. In practice, there is considerable illegal and semilegal trading in maize and rice because of inappropriate prices, inadequate storage facilities, or high marketing costs.

The storage issue is especially critical. In the recent food shortage in the country, although the shortage was blamed on a combination of bad planning, mismanagement, poor weather, and blatant profiteering, a large measure of the blame should have been placed on the lack of proper attention to storage facilities. The Financial Times (28 July 1980) had this to say: "Indeed, the poor maintenance of storage facilities may have been a factor in the apparent disappearance of the maize reserve. For example, at Nakuru only four of the 30 silos which form storage for the country's strategic reserve are properly water- and air-tight. At Kitale, the other centre for the strategic reserve, 10 out of 36 silos are out of commission". This reflects the storage situation across the country.

The maize marketing system in particular has often been criticized (Gsaenger and Schmidt 1977; Smith 1978), but the government has been reluctant to change it.

Most smallholder export crops are also sold through specialized single-channel marketing boards or cooperatives. Prices are primarily those set by the international market less marketing costs. However, some boards weigh heavily their financial reserve position and often adjust prices to suit this objective.

Prices were rigged in favor of the settlers; an example is the formula for maize in the 1950s (Heyer 1976; Smith 1978). The export marketing boards were initially set up to protect the interests of white settler farmers. Heyer (1976) concludes that large farms are favored over small farms in many respects. In most instances this is because the marketing system operates better for crops favored by large farms. Table 32 indicates that wheat production, for example, is almost completely dominated by large-scale farms.

Most of the country's marketable surplus passes through parastatals and cooperatives that operate without competition, and some of which are clearly not as effective as they could be. In this light, then, it is imperative that the government reconsiders the institutional setting in marketing. In some cases it would be economically prudent to allow effective competition between parastatal, cooperative and private bodies dealing in various crops. The government has started examining the roles of various parastatals in order to improve their performances. But here the words of Heyer (1976) are appropriate when she observed that there are "political interests that prevent changes from being made. There are the vested interests in large-scale farming, the vested interests that prevent the marketing system from divesting itself of its large-farm bias, the vested interests in the marketing system itself that are against disbanding the centralized organization, and the vested interests in cheap and limited credit".

4.6.3 Credit Policy

Agricultural credit is provided through commercial banks, cooperative societies, individual crop authorities and several specialized government institutions, the most important of which are the Agricultural Settlement Fund and the Agricultural Finance Corporation (this is to be converted into an Agricultural Bank).

The Kenya credit system has many shortcomings. It has failed to reach most of the small-farmers, it is not properly integrated into the overall financial system, and it charges too low interest rates (Heyer 1976; Long 1978; Donaldson and Von Pischke 1973).

Provision of credit in the past has tended to widen rural income disparities (Heyer 1976). Smith (1976) has also added to this evidence when he speaks of credit as "a useful

TABLE 32 Selected statistics for smallholders, large-scale farmers, and pastoralists.

	Smallholders	Large-scale farmers	Pastoralists	TOTAL
Maize (1976)				
Area (hectares)	1,860,000[a]	74,300		1,934,000
Production (tonnes)	2,158,000	309,000		2,467,000
Yield (tonnes per hectare)	1.16[a]	4.54		1.3
Wheat (1976)				
Area (hectare)	–	135,000		86,600
Production (tonnes)	–	187,000		187,000
Yield (tonnes per hectare)	–	1.4		1.4
Tea (1976–77)				
Production (tonnes)	27,720	58,571		86,291
Yield (tonnes per hectare)	0.64	2.37		1.26
Livestock[b]				
Dairy	1392	290	1980	
Beef	5559	157		
Sheep and goats	6959	326	9000	
Credit (thousand K£) (1976–77)	12,300[c]	8651		
Gross marketed product (1977) (million K£)	209	206		415
Population (millions)	10.11	0.52	1.29	

[a]Average area and yield. Smallholder maize consists of: (a) 480,000 hectares of hybrid maize, of which about 50% is in pure stands and the remainder in mixed stands; (b) 1,190,000 hectares of local varieties, of which 20% is in pure stands and the rest in mixed stands.
[b]Statistical Abstract 1977; A Brief Review of Farming Activities 1978 (Kenya Central Bureau of Statistics).
[c]Including cooperatives.

method of redistributing income in favor of those who are fortunate enough already to own sufficient resources to meet the minimum required for credit recipients".

More fundamentally, Kenyan agricultural policy makers and aid agencies have overemphasized the role of credit to the neglect of other important development constraints (Von Pischke 1976).

4.6.4 Agricultural Research Policy

Kenya has one of the largest agricultural research establishments in Africa, which allocates a substantial amount of resources for agricultural research. Table 33 shows planned resource allocation for agricultural research in the fourth Development Plan.

The major criticism of agricultural research policy has been its bias toward the problems of large farms and cash crops, i.e. coffee, tea, pyrethrum, sisal, and wheat. This concentration on large-scale farming has tended to exclude small-scale farming and so in most instances has indirectly resulted in negative effects on the distribution of rural incomes.

Gerhart (1975), however, has observed that the development of higher-yielding and drought-resistant strains of maize has been a major result of past research that has been

TABLE 33 Agricultural research provisions (K£) to government institutions during the period of the 1979–83 Development Plan.

	Agricultural research provisions, 1979–83 (K£)				
	1978–79	1979–80	1980–81	1981–82	1982–83
Recurrent research	5,811,897	6,351,945	7,573,364	8,742,472	9,947,390
Development research	3,805,081	4,971,410	4,659,040	4,937,000	5,092,330
TOTAL	9,616,978	11,223,335	12,232,404	13,679,472	15,039,720

SOURCE: Fourth Development Plan, 1979–83.

widely applied on smallholdings; the drought-resistant varieties have also been suitable for areas of lower potential. In the period 1964–73, production of hybrid maize in Kenya grew to an estimated 800,000 acres with a rate of diffusion higher than that for hybrid corn in the US in the 1930s (Gerhart 1975).

Such technological breakthroughs are not envisaged in the future, as is clearly stated in the fourth Five Year Plan (Government of Kenya 1979). This state of affairs could be improved if some of the resources withdrawn from maize research were restored to that area.

The government has also outlined in the same plan the direction of future agricultural research. It states that "Increased emphasis, including greater investment of human and financial resources, will be placed on those lines of agricultural research that are appropriate for land use intensification in smallholdings and on production techniques for areas of low and unpredictable rainfall. Research on developing viable mixed crop and livestock systems for arid areas will be emphasized. In the allocation of research resources preference will be given to research which is likely to increase both employment and productivity".

There will be some lag, however, before the intentions outlined here begin to redress the effect on income distribution that past research has had.

The major constraint in the future development of agricultural research and its potential contribution to agricultural development is the lack of qualified staff. One of the main reasons for this is the unattractive salaries (Ruthenberg 1978). The government would therefore need to provide ample finance for agricultural research and would need to organize it effectively, perhaps outside the regular civil service, to avoid some of these salary issues.

The present institutional arrangement does not permit competitive salaries to be paid, but the government has recognized this and founded the Kenya Agricultural Research Institute*; this may circumvent this problem.

Ruthenberg (1978) contends that the other major problem that seems difficult to solve is that Kenya is endowed with many different climates. This makes it difficult to conduct research on all of them effectively. This would therefore require that Kenyan researchers keep very much in touch with their counterparts working elsewhere in the tropics so that they can import innovations as soon as they become available.

*Founded by Act of Parliament in 1979 and located at Muguga, Kenya.

4.6.5 Extension Service Policy

Just as for agricultural research, Kenya has a large extension service establishment. Currently it has about 6000 employees. The government also devotes substantial resources to the agricultural extension service. There is a close connection between the extension service and research in that the latter transmits results to farmers and provides a feedback to researchers on the needs of the farmers.

The extension service has pursued what is popularly known as a "progressive farmer" strategy. In practice, those farmers regarded as most innovative and most likely to respond to advice are singled out for special attention on an individual farmer basis. These farmers are expected to "spread the gospel" to others.

All the studies that have analyzed this service in Kenya (Ascroft *et al.* 1972; Hunt 1974; Leonard 1977) have shown that the service is biased toward progressive farmers. There has also been a bias toward farmers who were given land in the government resettlement schemes. Staudt (1977) has further observed that the service has discriminated against women: "Women farm managers experience a persistent and pervasive bias in the delivery of the government agricultural services to which they are entitled. The bias increases as the value of the service increases. Moreover, the bias persists under a number of circumstances, including economic standing, size of land holding, and demonstrated interest in adopting agricultural innovations in a timely way".

For example, she found that 28% of farms jointly managed by men and women had never been visited by an extension worker, while the proportion was 49% for farms managed by women alone.

Past extension policies have been inegalitarian and have also widened disparities in agriculture. The progressive farmer approach accentuates this.

The Tetu experiment, and work elsewhere, has indicated strongly that focusing on "average" farmers through group extension methods is likely to be more effective (Ng'ethe *et al.* 1977; Leonard 1977; Schönherr and Mbugua 1974).

The fourth Development Plan (Government of Kenya 1979) has indicated an important shift in policy away from the progressive farmer strategy on individual farm visits: it states that "group extension programmes designed to reach more farmers will become the normal approach".

This approach will definitely meet with strong resistance from well-established extension agents who strongly support the progressive farmer strategy, as well as from the progressive farmers themselves. There is a natural tendency for extension services to drift toward the more progressive farmers. They respond and also demand service. Perhaps the main fault with the Kenya approach was to follow a laissez faire policy. Just as in research and other services, the change in policy here will need a great deal of political will on the part of the government as well as clear criteria for selecting group trainees and in devising an appropriate reward system. This approach, if it works, will definitely help in ameliorating the worsening income distribution in agriculture that has to some extent been created by the extension service.

4.6.6 Land Policy

Land policy is still one of the most crucial areas of agricultural policy in Kenya today. It is a major political issue and has been for decades. The most controversial land issue concerns the size distribution of holdings. This is not simply the question of large versus small. It is the question of access to land, and to a lesser extent the distribution of ownership within both the large- and the small-farm sectors (Heyer *et al.* 1976).

In this section, past land policies are first reviewed and then current policy and future strategy are discussed.

Past land policy since independence has concerned the resettlement of European farms and land tenure reform. The resettlement of European farms continues and has definitely had some impact on income distribution. The increased smallholder production has reduced rural poverty. This transfer of land from Europeans to Africans has especially reduced racial inequality, but on the other hand it has substantially increased inequalities between the resettled farmers and those remaining in their original smallholder areas.

Collier (1978) gives further evidence that shows that the distribution of land in Africanized large-farm areas is still highly concentrated and that cooperative settlements have made only a small contribution to redistribution. For example, in the mixed-farm area of Nakuru the distribution of all forms of ownership, such as proprietor, cooperative, partnership, private, and public company, is highly skewed, with 2% of farmers owning 69% of the land. Of the 18,115 owners, 16,500 held plots of slightly more than 1 hectare, while 38 farmers had farms in excess of 400 hectares.

Land tenure reform is also a continuing policy of the government. This policy has tended to improve the productivities and incomes of some smallholders but has at the same time worsened the incidence of landlessness and increased the concentration of land ownership.

Current and future land policy is mainly based on institutional changes. This is primarily the question of large farm subdivision. Little change is expected in the near future in the institutional setup of the plantation economy, i.e. coffee, tea, and sisal. The situation is different, however, with large-scale mixed farms. Here, subdivision is going on, albeit unofficially.

The fourth Five Year Plan (Government of Kenya 1979) has clearly spelt out the aims of official land policy, which is mainly directed to smallholder development: "The main lines of government policy are clear. The small-farm family that works on its own land is the main instrument for farm management and rural development. Exceptions to this style of agricultural production exist where economies of scale require other forms of organization, as with ranching, wheat farming, sisal and pineapple plantations, and nucleus estates. In the latter cases, the form of organization of the farming system, i.e. cooperative farming, limited liability company, partnerships, etc., will be determined by efficiency criteria. The emphasis on the small-farm family derives from evidence that, on the whole, small farms produce more per acre, utilize land more fully, employ labor-intensive methods of production, and are a source of subsistence as well as cash crops. The family farm as the focus for agricultural development has three implications which underlie more detailed government policies. First, the family owns its land. Second, the family manages its land. Third, the family works on its land. Ownership of large holdings of land suitable for small-farming will therefore be discouraged, and so will absentee landlords, a landlord–tenant system of farming, and the holding of idle land for speculative purposes".

The other measure that has been advocated to reduce concentration of land ownership and ownership for speculative purposes is a land tax. The government committed itself in 1973 to introducing a land tax as soon as adjudication and registration were complete, and the plan suggests that this process may begin in districts in which registration has been largely completed.

A land tax has many advantages, which are well summarized in Ruthenberg's words: "A land tax is the ideal instrument for income distribution without reducing the incentive for the better farmers. It is equitable. It is a minor charge for the man with little land and a major charge for the man with much land. It is a minor charge for the good farmer and a major one for the poor farmer".

The government has formed a National Land Commission and it is to be hoped that it will seriously study the issue of land tax. The National Land Commission should also investigate other policy instruments, such as a ceiling on land holdings or a capital gains tax, to see whether they can be used in reducing land concentration and the ownership of land for speculative purposes. Here again, though, a great deal of political will, rather than rhetoric, is called for.

The role of the government in bringing development to agriculture, especially smallholder development, has been emphasized throughout this report. However, this role should not be overemphasized, even when the political will is there. As Heyer and Waweru (1976) have pointed out: "The pace, pattern, and character of development in small areas is determined by a whole range of factors, only some of which are subject to influence by government. The initiative rests with the farmers, who can be persuaded but not forced to comply with particular policies". Nevertheless, the framework-setting policies concerning prices and markets, land, institutions, and organizations is critical to the development of agriculture to achieve the targeted output and employment, and hence the distribution of income desired.

5 PRODUCTION ESTIMATES

The Kenya Case Study (KCS) estimates are based on the best evaluation of the preceding analysis. Area and yield possibilities were considered separately for each crop, where feasible. Aggregate land estimates were modified by a realistic assessment of what additional land might be cultivated either in the semiarid zones or through irrigation and drainage.

It should be noted that these projections are to some extent speculative. They could possibly be improved by a more detailed analysis, but it is not clear whether any other estimates for the year 2000 would be much better.

5.1 Kenya Case Study Estimates

A summary is given in Table 34 of the crop production estimates for the year 2000. These estimates reflect a judicious mix of analysis and a strong component of common sense.

TABLE 34 Kenya Case Study crop production estimates for the year 2000.

Main commodity group	1976 figures: Area (thousand hectares)	Yield (tonnes per hectare)	Production (thousand tonnes)	Kenya Case Study estimate for 2000: Area (thousand hectares)[a,b]	Yield (tonnes per hectare)[c]	Production (thousand tonnes)[d]
Maize	1934	1.3	2467	2050	2.93	6006
Wheat	135	1.4	189	135	2.31	312
Rice	12	3.2	38	30	4.06	122
Millet and sorghum[e]	376	0.9	338	601	1.55	932
Pulses[e]	497	0.6	298	646	1.05	678
Roots and tubers	200	9.0	1800	392	13.49	5288
Fruit and vegetables	66	6.8	446	174	12.90	2245
Industrial crops						
Oil[f]	27		33	81		99
Sugarcane	85	19.5	1658	169	39.64	6699
Cotton	71	0.2	14	114	0.36	41
Barley	26	1.9	49	101	3.06	309
Tobacco	4	0.4	2	16	0.64	10
Export crops						
Coffee	87	0.9	78	120	1.27	152
Tea	66	0.9	59	87	1.45	126
Sisal	77	0.4	31	77	0.51	39
Pyrethrum	25	0.6	15	43	0.89	38

[a]The approach used in obtaining the hectarage was to assume that the percentage increase in hectares as given in the Development Plan for 1979–83 would triple for the period 1976–2000, except for tea and coffee.

[b]The resultant total change in hectares amounted to 1,040,000. About half this is expected to come from irrigation and drainage. The remainder can be obtained through expansion in semiarid areas, where pulses, millets, roots, and tubers are expected to show increases. Hectarage expansion through irrigation and drainage will be highly influenced by the cost of investing in irrigation and land reclamation through drainage, as well as by the availability of skilled manpower such as irrigation engineers and technicians. For coffee and tea the Ministry of Agriculture estimates land expansion at 38% and 32% respectively over the period 1976–83. We estimate that this target may be achieved by the year 2000.

[c]For the yield estimates, it was decided to take a value between the current average yield and the potential yield, i.e. that currently achieved on demonstration plots in Kenya. The yield growth rate y^* that would result in achieving this potential by the year 2000 was then computed. It was thought that half this rate, $y^*/2$, would be a reasonable achievement for the period 1976–2000. Thus the yield in year 2000 is given by the formula

$$\text{yield}_{2000} = \text{yield}_{1976}(1 + y^*/2)^{24}$$

[d]Production for the year 2000 was given by the formula $p_{2000} = \text{yield} \times \text{area}$. This same result could be obtained using the formula

$$\text{production}_{2000} = \text{production}_{1976}(1 + y^*/2)^{24} A_n/A_o$$

where A_n is the new area and A_o is the original area. A_n/A_o is essentially an area correcting factor.

[e]The apparent large acreage and low yield reflects the fact that millet, sorghum, and pulse production is from interplanted crops.

[f]Acreage estimate includes mixtures with cashew and cassava.

5.2 A Comparison of Kenya Case Study and Food and Agriculture Organization Production Estimates

The Kenya Case Study and the FAO estimates for the year 2000 are given in Table 35. The Ministry of Agriculture's figures for 1976 and 1983 are also given. There are some differences that require consideration.

Maize. The KCS estimate of 6 million tonnes is a gross estimate and, as discussed in Section 4.3.1, should be reduced by about 26% to give a figure of 4.44 million tonnes for unsifted maize. The FAO estimate of 3.2 million tonnes seems too low. The difference may be attributed to a low base year estimate by the FAO and also to their low expectations for yield gains. It is thought that the KCS estimate is more acceptable as its base

TABLE 35 Production estimates – Ministry of Agriculture (1976), FAO (2000), and Kenya Case Study (2000).

Main commodity groups	Production estimates (thousand tonnes) Current (1976)	Ministry of Agriculture (1983)	FAO (2000)	KCS (2000)
Food crops				
1 Cereals	3080	3983	5038	7372
2 Maize	2467	3139	3203	6006
3 Meat	187	200	777	312
4 Rice	39	65	129	122
5 Millet and sorghum	338	467	829	932
6 Pulses	298	420	750	678
7 Roots and tubers	1800	2341	3523	5288
8 Fruit and vegetables	214	371	3214	2245
Industrial crops				
10 Oils	33	52	17	99
11 Sugarcane	1653	3400	8480	6699
12 Cotton	16	34	30	41
13 Tobacco	0.8	3.7	2	10
14 Barley	49	112	100	309
Export Crops				
20 Coffee	80	112	195	152
21 Tea	62	109	153	126
22 Sisal	33	40	49	39
23 Pyrethrum	14	25	25	38
Livestock products				
30 Milk[a]	1160	1649	1537	2296
31 Beef	141	164	231	337
32 Sheep and goats	65	82	65	157
33 Poultry meat	28	39	120	99
34 Eggs	21	30	89	75
35 Pigs	3.2	4.4	29	10.1

[a]The Ministry of Agriculture estimates include milk products while the FAO and Kenya Case Study estimates are for whole milk.

year estimate and its estimate of the potential for improved yields by better seed and fertilizer use are based on more complete information.

Wheat. The FAO estimate of 777,000 tonnes seems too high in the absence of a concerted policy to change land use in this direction. At present this does not appear to be forthcoming, so the KCS figure, at 312,000 tonnes, seems reasonable.

Rice. The Kenya Case Study figure, at 122,000 tonnes, is about twice the FAO's 65,000 tonnes. Given current irrigation and drainage initiatives the KCS figure seems closer to the mark.

Millet and sorghum and pulses. The two sets of estimates are in reasonable agreement.

Roots and tubers. The Kenya Case Study estimate, at 5.3 million tonnes, is much higher than the FAO's 3.5 million tonnes. These are difficult crops to estimate, but the FAO base levels seem on the low side while the KCS estimate for increasing the hectarage by 100% and the yield by 50% may be overoptimistic.

Fruit and vegetables. Both estimates are substantially greater than the 1976 production of 214,000 tonnes. The FAO opts for an increase by a factor of 15, while the Kenya Case Study aims for what appears to be a somewhat more reasonable increase by a factor of 10. These estimates will be strongly influenced by the amount of investment forthcoming and by the ability of producers to increase their penetration of export markets.

Oils. The FAO estimate is unrealistically low, below even the Ministry of Agriculture estimate for 1976. Given recent Ministry of Agriculture policy initiatives, the KCS estimate of 99,000 tonnes seems feasible.

Sugarcane. The FAO estimate, at 8.48 million tonnes, is somewhat higher than the KCS estimate of 6.7 million tonnes. Kenya is rapidly approaching self-sufficiency in sugar and further expansion of production will be tempered by its ability to develop export markets. This in turn will require production costs to fall from their current levels. The KCS figure seems more realistic.

Cotton. The Kenya Case Study estimate of 41,000 tonnes is somewhat higher owing to the consideration of increased irrigation and drainage and improved marketing. Policy pronouncements seem to support this view.

Tobacco. The KCS estimate of 10,000 tonnes is based on the strong private sector input, especially by British American Tobacco. In the current political climate in East Africa, Kenya would appear to be well placed to increase its tobacco crop.

Barley. For barley also, the strong input from the private sector (Kenya Breweries) both for extension and marketing services indicates a substantial expansion for barley. The KCS figure of 30,000 tonnes by the year 2000 seems feasible.

Coffee. The Kenya Case Study estimates 152,000 tonnes, while the FAO suggests 195,000. The two are in reasonable agreement on yield, but the FAO seems to envisage a greater hectarage. Current knowledge in Kenya does not support the larger FAO hectarage figure.

Tea. The Kenya Case Study estimates 126,000 tonnes while the FAO opts for 153,000. Again, the FAO envisages a greater hectarage expansion but slightly lower yield gains.

The specific ecological milieu suitable for tea suggests that the FAO may be unduly optimistic in its hectarage assessment.

Sisal. The two estimates are in reasonable agreement. If recent price increases continue, the FAO estimate of 49,000 tonnes may be closer.

Pyrethrum. The current plan calls for a major expansion of pyrethrum production to 25,000 tonnes by 1983. If current market conditions are sustained, the KCS estimate of 38,000 tonnes by 2000 can be achieved.

Milk. The KCS estimate of 2.3 million tonnes is somewhat higher than the FAO estimate of 1.5 million tonnes. In view of the current milk programs the Ministry of Agriculture will be obliged to make a strong effort in this area and will expect to achieve 1.6 million tonnes by 1983. The KCS estimate seems better.

Beef, sheep and goats. The current market situation and resultant policy measures suggest that production here will reach the higher Kenya Case Study levels of 337,000 tonnes for beef and 157,000 tonnes for sheep and goats. Given adequate investment and the development of export markets, these figures could be surpassed.

Poultry meat and eggs. The estimates are in reasonable agreement.

Pigs. The FAO estimate is perhaps too high at 29,000 tonnes. The present organization of the industry, coupled with various cultural traditions, preclude production very much in excess of the KCS figure of 10,000 tonnes by the year 2000.

5.2.1 Changes in Input Needs

These increases in output will necessitate some changes in inputs. Part of the increase is expected to come from area increases, but the vast majority is expected from higher yields.

5.2.2 Area

The increase in area will require some additional capital expenditure for land improvement, drainage, and irrigation. For current plan objectives it is envisaged that capital formation for agriculture will grow at 8.5% while that for central government is put at 5.2%. The total growth rate of capital formation is placed at 6.2%. This should be sufficient when combined with private investment to permit the modest growth rates needed for increased acreage to be fulfilled. The financing of investment was not particularly difficult for Kenya up until the late seventies. Over the period 1970–79 domestic savings averaged 72.6% of investment, with the remainder financed by external loans and grants. Kenya was luckier than many developing countries as the sharp oil price increases were cushioned by a large increase in coffee export prices. However, the adjustment problems are now beginning to place severe constraints on the balance of payments. This is compounded by an increased debt burden caused by steep rises in defence expenditure.

5.2.3 Yield

Yield increases reflect changes in technology. The envisaged levels of around 2.5 to 2.9 tonnes per hectare for maize and 2.3 tonnes per hectare for wheat, for instance, seem well within the bounds of technical feasibility by the year 2000. However, changes in technology are required to achieve these levels. In particular, major increases will be needed in a number of inputs. Some FAO estimates are summarized in Table 36. In this chapter the analysis suggests that targets for seed, fertilizer, pesticides, and labor should not pose too great a problem. The tractor estimates look somewhat daunting. If current energy costs are not moderated this may be an overestimate. In particular, smallholders simply do not have the capital. Perhaps the research efforts discussed for these sectors will yield some form of small hand tiller; this should also be helpful in keeping down energy import costs.

The Input–Output table for 1976 published by the Government of Kenya (1979 prices) estimates that total imports for agriculture were about K£11 million, or 2% of the gross output value of that sector. These represented less than 2% of total imports. Even with the dramatic changes envisaged, we should expect that the imports necessary for agriculture will not be a particular problem with regard to the balance of payments.

TABLE 36 Inputs to agriculture.

	FAO estimates	
	1975	2000
Seeds (for cereals)		
Traditional	46	16
Improved	19	98
Labor (10^6 man days)	493	936
Animals (thousand head)	800	1593
Tractors (thousand units)	7	144
Fertilizer (thousand tonnes)		
Nitrogen	23	150
Phosphates	18	118
Potash	3	31
Others	10	38
Land (thousand hectares)		
Good rainfed	1656	2248
Cropping intensity	0.92	1.15
Arable	1809	1955
Low rainfed	948	1986
Cropping intensity	0.64	0.60
Arable	1491	3310

5.3 Economic Policy

The role of prices, taxes, credit, and administrative measures in influencing profits and thereby the level and allocation of resources becomes more important while agriculture is undergoing rapid change.

5.3.1 Institutional Factors

In Kenya, as in most countries, various institutional factors play a major role in fashioning and implementing the pace and style of change. While in principle institutions may be created to fill various needs, in practice this is often a long and arduous task. The process in other countries has been documented by a number of researchers – see for example Hayami and Ruttan (1971) or Binswanger *et al.* (1978). Accordingly, it seems desirable to take a closer look at some of the present institutional arrangements to try to determine which features are relevant for Kenya. Agriculture and marketing policies are reviewed through the Annual Agricultural Price Review, the Office of the Price Controller, Inspectorate of Statutory Boards, and at the district level there is usually a strong input from the District Commissioner's office. The various parastatals and statutory boards wield a strong hand. Recently they have been the subject of much criticism, and major plans have now articulated the need to improve the performance of the Maize and Produce Board in particular (Ndegwa 1979). Recent analysis by Sharpley (1980), who incidentally was a member of the Ndegwa Commission charged with reviewing the statutory boards, suggests that in the case of marketing boards, cooperative societies, and processing firms, there may be considerable scope for reducing overheads. This would enable the share of the price received by the grower to be increased. In particular she suggests that one of the areas in which to reduce some overhead margins might be the Kenyan railway and post charges. This proposal merits consideration, as it is important to try to increase producer farmgate prices without the usual problems of a corresponding increase in consumer food prices or a heavier fiscal burden.

The role of these boards has also been questioned with regard to the implicit redistribution that some of their policies entail. Thus the low producer prices for beef are passed on to the higher income groups in Nairobi (von Kaufmann 1976). Similarly Schmidt (1979) has argued that smallholders could also have benefited from the reorganization of maize marketing.

It is important to realize that Kenya does have the ability to run a reasonably efficient marketing organization. Aldington (1979) noted that organizations handling coffee and tea seem to have a much better record than those handling the domestic commodities. Unfortunately for smallholders, they are often at the receiving end of these shortcomings.

Similarly, Kenya has demonstrated the ability to mount an effective extension service for smallholder tea growers. Admittedly, the extension workers here may be higher paid and better motivated so that the results are quite good. It also indicates that the smallholder does respond when there is something to extend. Consequently, recent efforts to reorient the extension service toward a broader range of smallholders do have some precedents for success.

In the present transitional situation, in which modern agriculture is becoming increasingly based on purchased inputs in contrast to inputs generated on-farm, it is desirable that the price structure provide an economic incentive to use the most advantageous inputs.

In the longer term it is inevitable that market forces of supply and demand are the basic determinants of price levels. However, the government can attempt to modulate the operation of market forces to improve the economic environment in a number of ways.

It can implement a system of support prices, announced in advance of sowing and backed up by guaranteed purchases, to provide a minimum expected price to reduce the risk in taking production decisions. Kenya does have support prices for a number of commodities such as maize and wheat, but the effectiveness of this policy is often limited by the inability to announce the prices far enough in advance to allow farmers to adjust their planting decisions.

For other commodities it can provide some degree of price stability from year to year and season to season to minimize economic waste due to inefficient production, marketing, and consumption decisions. Support prices provide the lower limit for harvest prices. Seasonal prices might be allowed to rise above the harvest price level to encourage proper storage investment.

Government policy can seek to correct supply–demand imbalances in specific commodities so that undesirable substitution effects in production do not occur.

Currently the government operates a national food reserve system through the Maize and Produce Board. The stipulated national reserve is 2 million bags per year. The Maize and Produce Board stocks have fluctuated between 2 and 5 million bags. The cost of storage per bag (90 kg) has been KSh8.50, and consequently the total cost of storage has ranged between K£850,000 and K£2,125,000 (Maize and Produce Board data). This cost could be met by increased consumer prices, but the government has been reluctant to use this tool. On the other hand, the Treasury has not been anxious to meet all the costs and the Maize and Produce Board has been and still is in debt. The decision on who should pay for this rests more in the realm of politics than of economics. The recent decision to lower the maize price to producers from KSh85 to KSh65 per bag (90 kg) placed the burden on the farmers.

The 1979–80 maize crop failure moved the debate to the center of the stage. The short-term policy was to move the maize price back up to KSh80.

This argument may be used in support of requiring all taxpayers, rather than consumers, to foot the bill for maintaining a national reserve, especially of maize, since transferring the cost to consumers would have a severe impact on the poor.

The maintenance of a buffer stock would be paid for by the same group of people. However, the cost of a buffer stock is found to be less than the current cost of maintaining the national reserve, since a buffer would not be as large as the national reserve. The population would be still better off if the current spending level of K£2 million could be reduced.

5.3.2 Taxation

The incidence of taxation in Kenyan agriculture is low. While there is ample scope for research in this area, the probability for implementing higher taxes is low primarily for political rather than economic reasons. Kaplinsky (forthcoming) suggests a number of areas where multinationals wield a particularly heavy hand. One company continues to announce low or negative profits for Kenyan tax purposes yet seems willing to increase its investments year after year! Nonetheless, taxes are costs. They may have an undesirable disincentive effect on the use of some important inputs such as fertilizer. On the other hand, taxation on selected inputs may be a flexible method to shape private decisions toward more socially desirable goods.

Taxes have many different effects. The overall influence of the taxation policy must therefore be assessed in conjunction with the influence of other policies to determine the net economic effect.

The introduction of a land tax should be given serious consideration. It could encourage more intensive land use and could curtail the holding of land for speculative purposes. It could also encourage the subdivision of large farms, many of which are not made economic use of at the moment. A well-designed tax package would stimulate employment and would help toward a more equitable distribution of incomes.

In general, to promote agricultural development the taxation system should encourage sound land use and resource allocation, exports, import substitution, the use of labor, and the development of the small-farm sector. The system might also include selected export taxes for products that face favorable market conditions, as do coffee and tea at present. However, the overall system should be flexible enough to allow for unpredictable factors such as the weather or sharp market changes.

5.4 Summary

The FAO seems to have underestimated maize, milk, beef, sheep, and goat production primarily because its base year estimates are low and because in the case of maize it does not envisage reasonable yield gains. Some of their pessimism about maize is compensated for by a higher wheat estimate. In the Kenya Case Study it was thought that lack of suitable land will restrict wheat production to about half their estimate. For coffee and tea it was thought in the Kenya Case Study that the FAO estimates are on the high side because of their unduly optimistic expectation of increased hectarage.

All these estimates could be changed substantially by many factors. While many of these factors are outside the control of government, such as the weather, prices of imported inputs such as tractors, petroleum, and most exportables, there are many policy initiatives available. In the export area Kenya could move strongly towards the production of vegetables, fruit, and meat. This is particularly desirable in view of the balance of payments. However, it is essential to maintain progress in domestic staple production, as the growing demand driven by high population growth could easily result in disastrous consequences for the balance of trade. There are many examples of countries that have achieved success in relatively short periods of time. Immediate examples are the soybean and citrus fruits in Brazil or cassava in Thailand. Success at this level would require a major reorientation from current urban-oriented development toward agriculture and agriculture-based industry. In particular, manufacturing investment incentives could be weighted toward agrobased industries.

6 CONSUMPTION AND PRODUCTION – POLICY IMPLICATIONS

6.1 Consumption–Production Balance

In the previous sections consumption and production have been discussed separately. In reality they evolve interactively to a greater or lesser degree for various commodities. In some instances price serves as an equilibrating mechanism, falling in the case of excess supply and rising where shortages occur. For many commodities prices are controlled, with the result that inventories are built up in times of surplus (e.g. for maize in 1979), while various unofficial markets develop during periods of shortages. Some of the broad aspects of consumption and production are reviewed in what follows before we present a more detailed consideration.

6.1.1 Consumption

The primary forces determining consumption patterns by the year 2000 should be population growth, increased urbanization, and purchasing power. The population is expected to have doubled its current level, i.e. to have reached about 30 million by that time*. Population policy poses a number of problems. The current plan indicates a desire on the part of the government to curb population growth. A high population has some positive side-effects, but it is desirable to have a balanced growth so that structural transformation and improved living standards can be harmonized.

Increased urbanization will have a number of effects. It is anticipated that 20% rather than 38% of the total population will be directly employed in agriculture. This implies that agricultural labor will be required to show a substantial increase in productivity. The other major influence on agriculture will result from the urban consumption pattern being somewhat different from the rural one. Across all income groups the urban dweller tends to consume more wheat (bread) and rice but less total cereals, particularly millets and sorghum, and less roots and tubers. He also consumes more meat, fats and oils, sugar, and beverages. These trends in national consumption patterns can be expected both to induce change in the composition of production, and to be influenced in turn by the changing nature of production.

By the year 2000 overall production should increase by 100% or more for most commodities. Only a limited portion of this increase will be achieved by land-augmenting policies involving irrigation and drainage schemes**. This will primarily affect rice and horticultural products. The increase in production will be achieved most cost effectively by higher yields and improved cropping practices rather than by augmenting land. The technology to achieve these yields will require more and better inputs, primarily fertilizer, seeds, herbicides, and pesticides.

Much of the increase will come from the smallholder. This will require a major reorientation of the extension service. Up until now the extension service, and indeed most agricultural policy, has been largely oriented toward the large-farm sector and the "progressive" African farmer. To some extent this may have been justified in the past when these farms were essential in generating a surplus for both the domestic and the export market. Much of agricultural policy was heavily involved in the transfer of land from European owners and this tended to limit the availability of funds for other initiatives. With most of these land transfers completed, increased resources can now be directed toward improved agricultural performance, particularly by smallholders.

With less of the population involved in direct agricultural production, the marketing system will need to be developed with the increasing new demands *pari passu*.

6.1.2 Consumption–Production

The "most likely" *ex ante facto* scenarios for consumption and production are shown in Table 37. It appears that certain adjustments are unavoidable to produce equilibrium.

Maize. According to the Kenya Case Study the production (after allowing 26% for seed and various losses) should exceed demand by a few hundred thousand tonnes. It should be emphasized that these are long-term forecasts. For short-term policy decisions, particular attention must be paid to year-on-year fluctuations. Thus the 1979 maize crop was about 30% below trend owing to a combination of factors that included poor weather

*The Economic Survey (1979) estimates the population growth rate at 3.9%. This would result in a population of about 34.4 million in the year 2000.

**In Section 4 it was estimated that we might expect about 400,000 additional hectares.

TABLE 37 Production–consumption balance: major food items for Kenya in the year 2000 (values given in thousand tonnes).

	Demand scenario[a]	Production (KCS estimate)	Demand (FAO estimate)	Production (FAO estimate)
Maize	4178	6606[c]	2551	5038
Millets–sorghum	414	932	553	829
Wheat	550	312	819	777
Other cereal (rice)	189	122 (rice)	124	129 (rice)
Potatoes	908	5288	447	3523
Cassava	720		1117	
Sugar	496	670[d]	618	848[d]
Pulses	617	678	798	750
Milk	3092	2296	2273	1537
Meat and fish	970	593[e]	947	416[e]
Fats and oils	121	99[a]	137	17[a]
Fruit and vegetables	917[b]	2245	997[b]	3214

[a]Estimate does not include fats.
[b]Vegetables only.
[c]This figure should be reduced by 26% to take account of seed and other losses.
[d]Based on a 10:1 conversion factor.
[e]Excluding fish.

and the absence of a government guarantee of adequate return. Historically, about two bad harvests in 10 can be expected for Kenya, and planning should allow for this through various stock security measures. This *ex ante facto* excess supply can be reduced by (a) a fall in the real price of maize, or (b) the development of alternative markets and uses.

Since much of the production is by the rural poor, any precipitous fall in price would have severe negative welfare implications for those producers who depend on some sales for cash income. On the other hand, current market prices exclude Kenyan maize from the world market. The free on board export price might be reduced to some extent by reducing some costs; in particular, the current storage approach needs improvement.

A recent analysis by Sharpley (1980) suggested that transportation and handling costs also leave considerable room for improvement. Maize could also satisfy some of the domestic industrial needs but the required investment in processing plant would need government support, at least in the early stages.

The Guaranteed Minimum Return Scheme (GMR) supported much of large farm production but encountered major repayment problems.

Millets – sorghum. The supply will exceed domestic human consumption. Some of the supply will probably be used for animal and poultry feed.

Wheat and rice. Consumption will exceed domestic supply unless policies are modified. This will be a burden on foreign exchange unless domestic production can be increased by higher relative prices.

Potatoes and cassava. Here we find that potential production is far in excess of the envisaged demand. Again, alternative markets are desirable. The pelleting plant proposed at Mombasa geared toward the European market would appear to be a step in the right direction. Even here caution must be exercised as the market might be unduly perturbed by changes in prices for European protein sources use to complement the cassava.

Sugar. It seems that supply will rapidly exceed domestic demand. Before continuing current sugar policy, it is desirable to identify the market for this excess supply. Otherwise much of the investment currently earmarked for sugar should be rechanneled into other products.

Milk. Demand and supply will be reasonably well balanced on allowing for butter and cheese uses.

Meat and fish. The demand for meat will exceed supply unless measures are taken to improve production.

Fats and oils. Production of vegetable oils needs to be encouraged in the near future by providing the necessary infrastructure for processing and marketing.

Fruit and vegetables. For both these there is also a potential excess supply which could be channeled into the export market with proper planning.

6.2 Income Distribution

Recent development policy in Kenya has produced the classic urban–rural duality. Investment in the relatively prosperous urban areas has been closely linked to a relatively free hand for the multinationals. Most money going to the rural areas has gone toward purchasing farms from Europeans, with relatively little investment in productivity. Inevitably this has resulted in a fairly skewed income distribution. It remains to be seen whether income distribution by the year 2000 will be shaped by the interaction of similar sociopolitical and economic forces.

While some of these may be predicted, inevitably many of them will be unexpected. Currently there is a sharp dichotomy between rural and urban sectors. Rural areas, where most of the population currently reside, are characterized by a large number of smallholders, pastoralists, and landless at one end of the income range with a small number of relatively wealthy farmers at the other end. There are about 1,500,000 smallholders and 3000 large-farmers. The distribution of incomes among agricultural households is relatively even. Lijoodi and Ruthenberg (1978) estimate a Gini coefficient (see p. 80) of 0.49 for this group, which is considerably less than typical estimates of around 0.60 for Kenya as a whole. The production structure for large and small farms is different both in terms of the cropping patterns and the technology used. There is little or no middle class in the conventional sense.

The urban areas, on the other hand, have only about 13% of the population at present. Average incomes here are about five times higher than rural levels. At the lower end of the urban income range are the unemployed and the working poor, while at the upper end are the entrepreneurial and professional classes. The urban areas do have a small but growing middle class. This includes civil servants, intermediate entrepreneurs, and skilled workers. It is interesting to surmise what will evolve if the current policy is continued in the near future, and also to predict what the outcome might be of significantly changing this policy. First the "current" situation is reviewed.

6.2.1 National Income Distribution

The estimation of income distribution is a perilous pursuit in most countries. On the one hand, radicals feel they can promote their cause by emphasizing how unequal it is, while many of the establishment often feel subject to attack when their policies lead to a more inequitable distribution. In the context of Kenya these discussions become even more perplexing owing to a number of particular features. First it is not clear to what extent people perceive the relative importance of absolute rather than relative income levels. Does a reasonably successful pastoralist in Samburu cast a longing eye at the higher income of a laborer on a Nairobi construction site? Secondly, there are very substantial differences in what may be necessary for an urban or rural family. Those that come to mind immediately are housing and transportation costs. For these reasons it seems that relative incomes assert their importance for people who live in similar locations and are exposed to and conditioned by similar sociocultural values. It therefore seemed more appropriate to consider urban and rural dwellers separately in the earlier sections. However, we can persist in looking at the overall national picture if we bear these reservations in mind.

6.2.2 Income Distribution in 1976.

An estimate of the income distribution in Kenya for the base year, 1976, is given in Table 38. This is obtained by combining the estimates for urban and rural groups developed in Section 2. In reality there would be some overlap between these groups, but for convenience they are ordered by the average income per capita for each group. At the lower end of the range are the rural poor, who are mostly pastoralists, landless and poor smallholders, while at the upper end are the urban rich. This is not particularly surprising, even though some eyebrows might be raised at the relative income difference

TABLE 38 Estimated income distribution in Kenya in 1976[a].

Group	Share of population (per cent)	Share of income (per cent)	Annual income per capita in Kenya pounds (1976)	Calorie[b] intake per capita per day
Pastoralists, landless, poor smallholders	34.7	7.54	16.4	1620
Smallholders	34.7	17.31	37.5	2070
Urban poor	5.3	4.93	69.0	1900
Rural rich	17.3	28.92	125.4	2800
Urban middle income	5.3	17.12	242	2200
Urban rich	2.7	24.18	683	2500
TOTAL	100.0	100.0		

Average per capita income in K£ (1976):	75.2
Average per capita daily caloric intake[c]:	2050
Population in millions:	13.75

[a]National estimate obtained by combining urban and rural estimates from Section 2.
[b]Estimate derived from Frohberg and Shah (1978) and Smith (1978).
[c]The FAO estimate for 1974–76 is 2151 calories.

between these groups of more than 40 to one. What may be surprising to some is the ordering of some of the intermediate groups. Thus the urban poor, with an average per capita income of K£69 (1976), are ranked above rural smallholders. However, in terms of at least one welfare measure, caloric intake, the ranking should be reversed. This is typical of the issues that are masked in looking at an overall national picture.

6.2.3 Nutritional Status

Caloric intake is often used as a measure in assessing nutritional status, but it should be so used only with reservation: many other factors need to be considered. There are food studies available of the nutritional status of large populations. Small-scale studies and a recent study of Tunisia by Kamoun and Perisse (1979) suggest a strong correlation between nutrient intake and nutritional status. Other determining factors include health and metabolism. If this correlation is accepted then a further link, to relate food intake to nutrient intake, is needed. In most societies an adequate calorie intake seems to ensure the satisfaction of nutrient requirements. The more obvious exceptions are in regions where the diet is heavily dependent on low protein staples such as cassava or manoic. This situation arises in Western Kenya. If an individual is not meeting his caloric requirements, it is evident that the intake needs to be increased if his nutritional status is to be improved. However, this is a necessary but not a sufficient condition; for instance, his state of health also needs consideration.

There is also a considerable diversity of opinion on what caloric requirements should be. At the aggregate level these are usually estimated by considering such variables as weight, age structure, sex, and working environment. The absolute lower limit for an individual to maintain body weight in rest conditions is defined as the basal metabolic rate (BMR). The joint FAO/WHO committee suggests 1.5 BMR as desirable. The present study chooses 1.2 BMR as a threshold for assessing malnutrition. Since the coefficient of variation is about 10%, this suggests that even in an adequately fed population about 2% of that population would have an intake below 1.2 BMR. This measure is used in the present analysis to assess the Kenyan situation. The 1.2 BMR critical limit for Kenya is estimated at 1517 calories per capita per day (World Food Survey, 1977). Thus we can presume that in most situations linkage between income, caloric intake, and nutritional status exists, but it should not be viewed as a definitively causal relationship.

6.2.4 The Current Situation

The current nutritional status for Kenya is reviewed in the Food and Nutrition section of the government's current plan. The situation is summarized in Table 39. Inadequate income is identified as a leading cause of protein energy malnutrition (PEM). Other causes, such as seasonal variations in earnings, lack of education, and poor food practices, are also listed. One estimate of PEM may be gauged from the Rural Kenyan Nutrition Survey (1977). About one third of all the children surveyed (in rural areas) had a weight-for-age index below 80% of standard. This index may be taken as a measure of mild and moderate PEM. The incidence of severe PEM was about 5%. The more comprehensive National Child Nutrition Survey (Central Bureau of Statistics, 1978–79) included children aged six months to five years in both urban and rural locations. The results of this survey indicate that the rural situation is essentially similar to that in the 1977 survey. In urban areas the figures are somewhat better, with about 20% malnutrition and of these about 5% in the severe category, similar to the rural situation. These data on children,

TABLE 39 Nutrition problems in Kenya, 1978[a].

Nutritionally deficient group	Nutrition problem	Cause of problem	Policies to alleviate problem	Estimated numbers in group
1. Smallholders				
Food crop producers average household income K£50 (1975), virtually no sales	Protein energy malnutrition (PEM)	Insufficient food production	Availability of improved inputs, hybrid maize, legume, and pulse production	2,200,000
Landless poor	PEM	Low income, consumer prices	Increased nonagricultural employment, public works, control of essential food prices	410,000
Cash crop producers household income K£125 (1975)	Periodic PEM	Low earnings poorly distributed throughout the year	Improved marketing, storage, stimulation of food production	1,090,000
2. Urban groups				
Unemployed, underemployed	PEM	Low income, consumer prices	Better employment opportunities, control of essential food prices	250,000
3. Pastoralists	Periodic PEM	Vulnerability to weather, lack of food security	Food security systems, better stocking practices, increased demand for produce	670,000
4. Special groups[b]				
Preschool children	30% mild PEM, 5% severe PEM	Inadequate household purchasing power, poor feeding practices, infection	Preschool feeding programs, nutrition education, more curative facilities	*c*
Pregnant and lactating mothers	Anemia	Poor diet, malabsorption infection, hookworms	Feeding programs, education, improved water supply	
Xerophthalmia bitot spots	Vitamin A deficiency	Poor diet, malabsorption	Increased availability of fruit and vegetables, improved water supply	
Goiter	Iodine deficiency	Endemic, particularly in Western Nyanza and Rift Valley Provinces	Iodization of salt	

[a]This is not a comprehensive analysis but is indicative of the situation.
[b]There are many other nutritional and nutritionally related problems that tend to be either more local or not as pervasive as those listed, but that would be included in a more comprehensive study.
[c]Estimates are not given, since many overlap those in groups given above.
SOURCE: Development Plan 1979–83, Government of Kenya.

together with food intake data and analysis of other surveys (these include Bohdal *et al.* (1969), Blankhart (1974), the Report on the Nutritional Status of Mwea-Tabere Irrigation Scheme Community (1978), and the Summary Report of a Workshop on a Food and Nutrition Strategy for Kenya (1975)), suggest that about 31% of the population suffer from some degree of PEM and do not have an adequate intake to satisfy their requirements. On using the 1.2 BMR standard, about 17% of the population in the rural area is in that category. The results of the National Child Nutrition Survey (1978–79) suggest that for urban areas the proportion in the mildly undernourished category is a little lower, but that the severely malnourished category is about the same size.

Average caloric intake per capita per day for each group is also given in Table 37. While these caloric intake estimates (for urban and rural groups from Frohberg and Shah (1978) and for rural groups from Smith (1978)) are positively correlated with income in both urban and rural sectors, this correlation does not hold at the national level. The caloric intake levels may be changed by changes in purchasing power. This is particularly true for the low income groups, where food dominates the expenditure pattern. This can be seen from Table 40, where food expenditure shares vary from 0.77 to 0.21 for different groups.

TABLE 40 Food consumption patterns by income group.

Group	Share of income spent on food	Share of expenditure spent on food	Expenditure elasticity for calories
1. Rural low income	0.80	0.77	0.74
2. Rural middle income	0.48	0.75	0.67
3. Urban poor	0.62	0.45	0.38
4. Rural rich	0.32	0.73	0.48
5. Urban middle	0.37	0.37	0.34
6. Urban rich	0.18	0.21	0.25

SOURCE: Income and expenditure shares are computed from the Integrated Rural Survey 1 (1974–75) and the Urban Food Purchasing Survey (1977). Elasticity estimates are computed fom the calorie expenditure data derived by Frohberg and Shah (1978) and Smith (1978).

Thus to the extent that nutritional status is determined by income, the problem may be considered as one of inadequate income for the low income rural and low income urban groups. Figure 1 shows a plot of per capita caloric intake against expenditure. The population histogram superimposed on this figure suggests that about 33% of the rural population have an intake of below 1800 calories per capita per day and included in these are about 17% of the rural population with an intake below 1517 (1.2 BMR).

The 1800 level is used as a measure for mild to moderate PEM, while 1517 calories is used as the datum for severe PEM.

6.2.5 Present Planning Direction

At this stage it is of interest to estimate what the likely impact on malnutrition will be by the year 2000 if the current planning direction is maintained. This situation is closely approximated by Scenario 4 (summarized in Table 21). The income distribution for

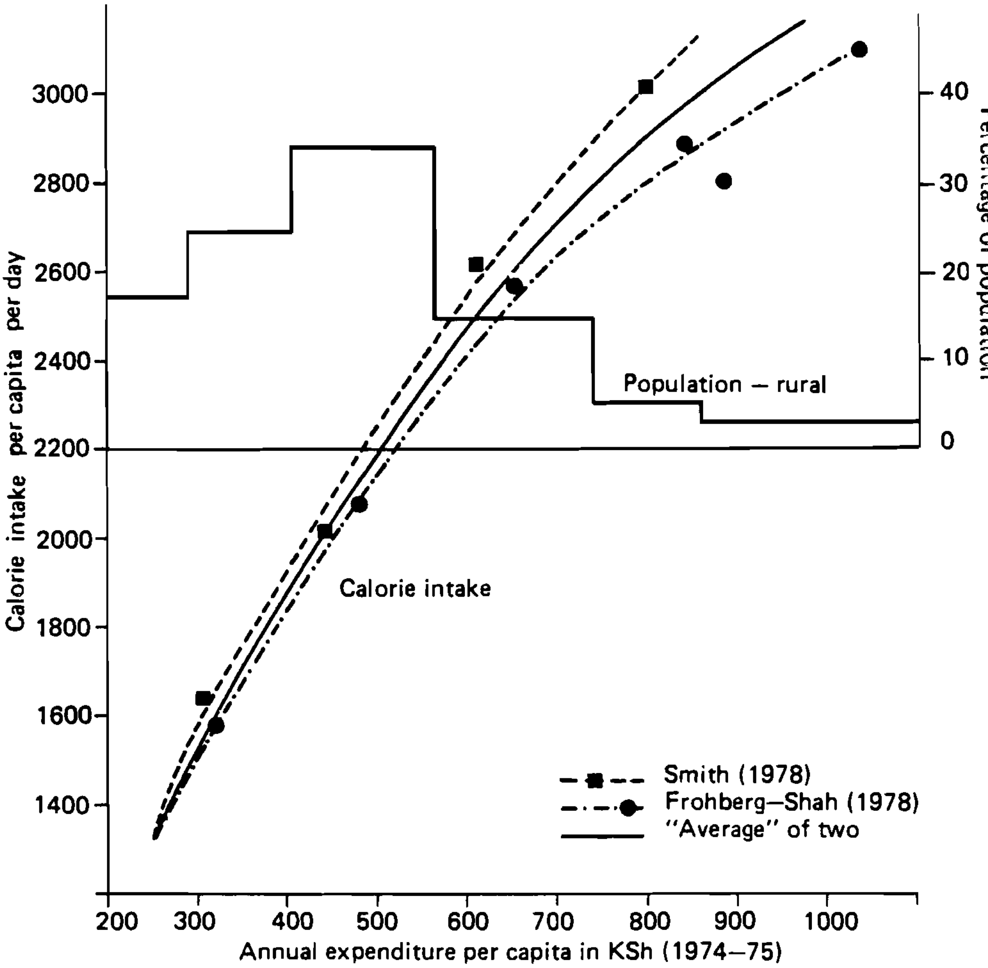

FIGURE 1 Calorie intake versus expenditure for rural Kenya (1974–75).

Scenario 4 is shown graphically in Fig. 2, together with the 1976 distribution (Scenario 1) and the major redistribution test scenarios. If per capita incomes in urban and rural sectors are unchanged, note that national income distribution as measured by the Gini coefficient (see Appendix) will become more skewed. The underlying mechanism that produces these seemingly paradoxical results is that the rural poor maintain their real wage, but there is a larger proportion of people in the urban sector assumed to have the higher real wage there. Thus without real per capita growth *within* each sector it can be expected that the percentage malnourished in rural (33%) and urban areas (20%) will remain unchanged. There will be some improvement in the national figure, however, because of the higher growth rate for the urban areas.

6.2.6 Real Per Capita Income Growth (Scenario 4)

The current plan calls for an annual real income growth of about 1% per capita. Let us suppose that this can be maintained to the year 2000. On average this means that

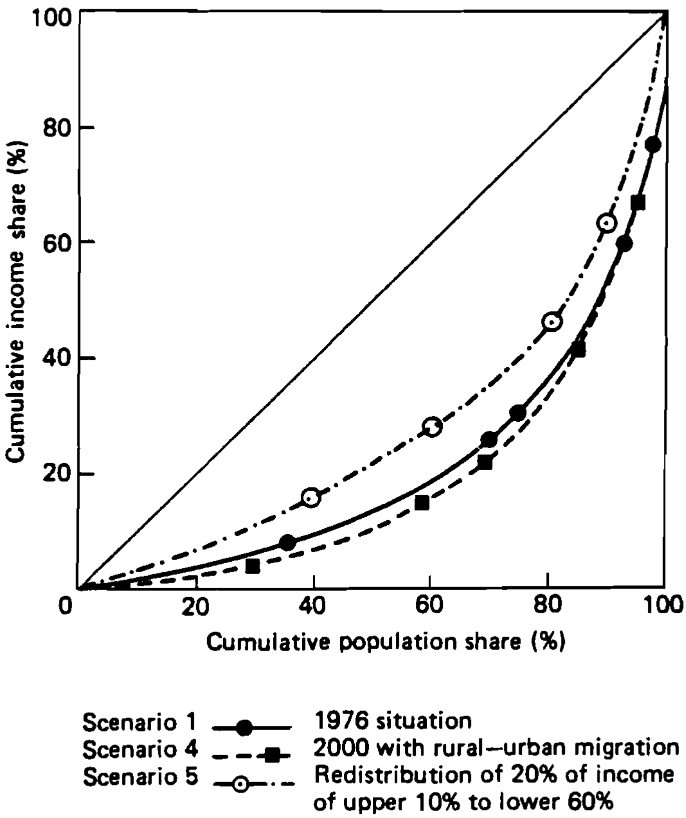

FIGURE 2 Income distribution in Kenya.

within the urban and rural sectors there will be a per capita growth of about 27%. Again, the national average growth rate will be much higher because it is assumed that the urban sector can indeed absorb the high number of rural-to-urban migrants at average urban wage levels. Note that the income distribution will still become more unequal, as shown in Fig. 2.

The caloric intake of the low income rural group should rise by 20%, however, while that of the low income urban group should rise by 10%. The overall impact on nutrition may be approximated from Fig. 3. The cumulative population curve is moved to the right by an amount corresponding to the change in expenditure for each group.

Thus the 27% expenditure gain produces a nonlinear shift, with those at the low end gaining little in absolute terms while those around the 350 KSh level gain a rather substantial 94.5 KSh. Redrawing this curve (Fig. 4) indicates that in this case only about 20% of rural dwellers will remain below the 1800 calorie datum for mild and moderate malnutrition with 11% below the 1.2 BMR level. A similar analysis for the urban sector (Fig. 5) indicates that those below the mild-to-moderate PEM datum will drop from about 20% to 14%.

6.2.7 Income Redistribution (Scenario 5)

In this section we consider the possibility of a major income redistribution. The particular form assumed is summarized in Table 21 as Scenario 5. From the norm, Scenario 1

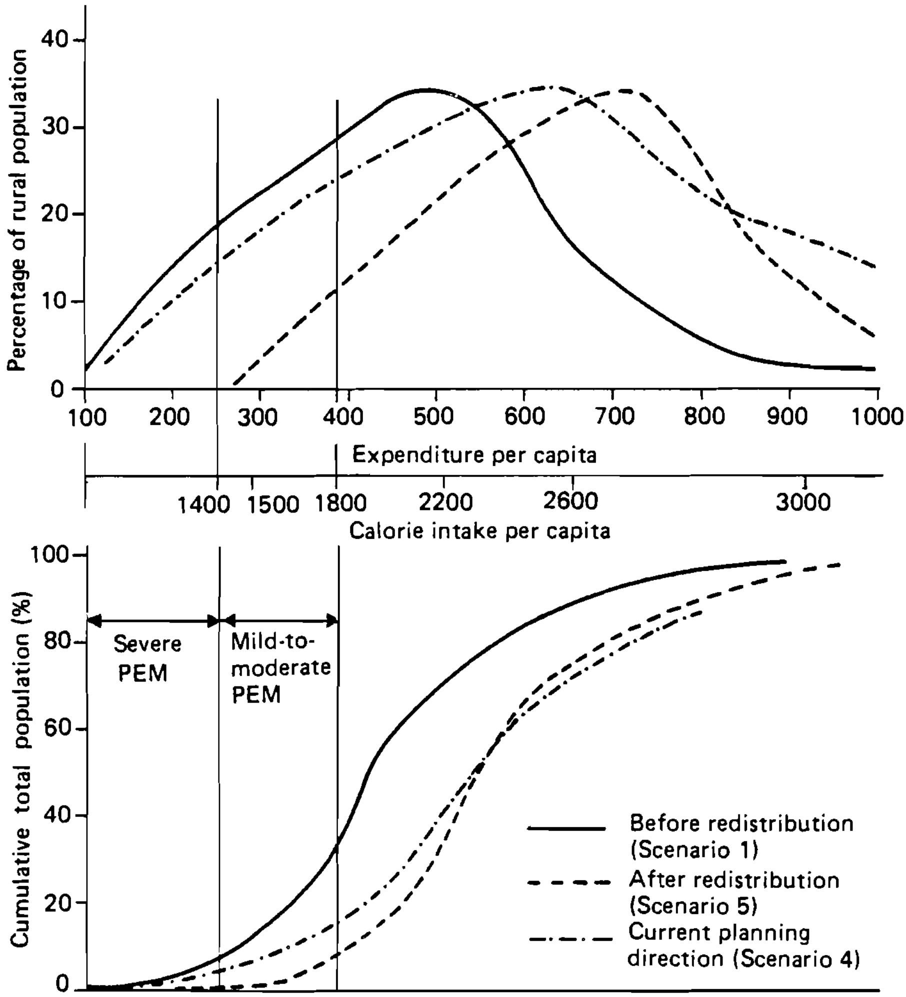

FIGURE 3 Income redistribution at the national level – the impact on the rural population.

(income distribution as in 1976), the following adjustment is made. A slice of 20% of the income is removed from the upper 10% of the population. This reduces their share from 0.457 to 0.366. This income slice is then distributed *equally* (on a per capita basis) to those in the lower 60% of the population. This produces an income gain of 66% for those in the lowest 40% class and a gain of 32% for those in the 40–60 group. (It should be emphasized that it is extremely unlikely that an income redistribution of this magnitude could be achieved without an intervening period of severe dislocation.)

The redistribution on an equal per capita basis is particularly significant for those at the low extreme of the income spectrum. They each receive KSh236; thus the whole population curve is moved laterally through roughly this substantial amount at the lower end. This shift is shown in Fig. 4. On the cumulative curve it is noted that the percentage

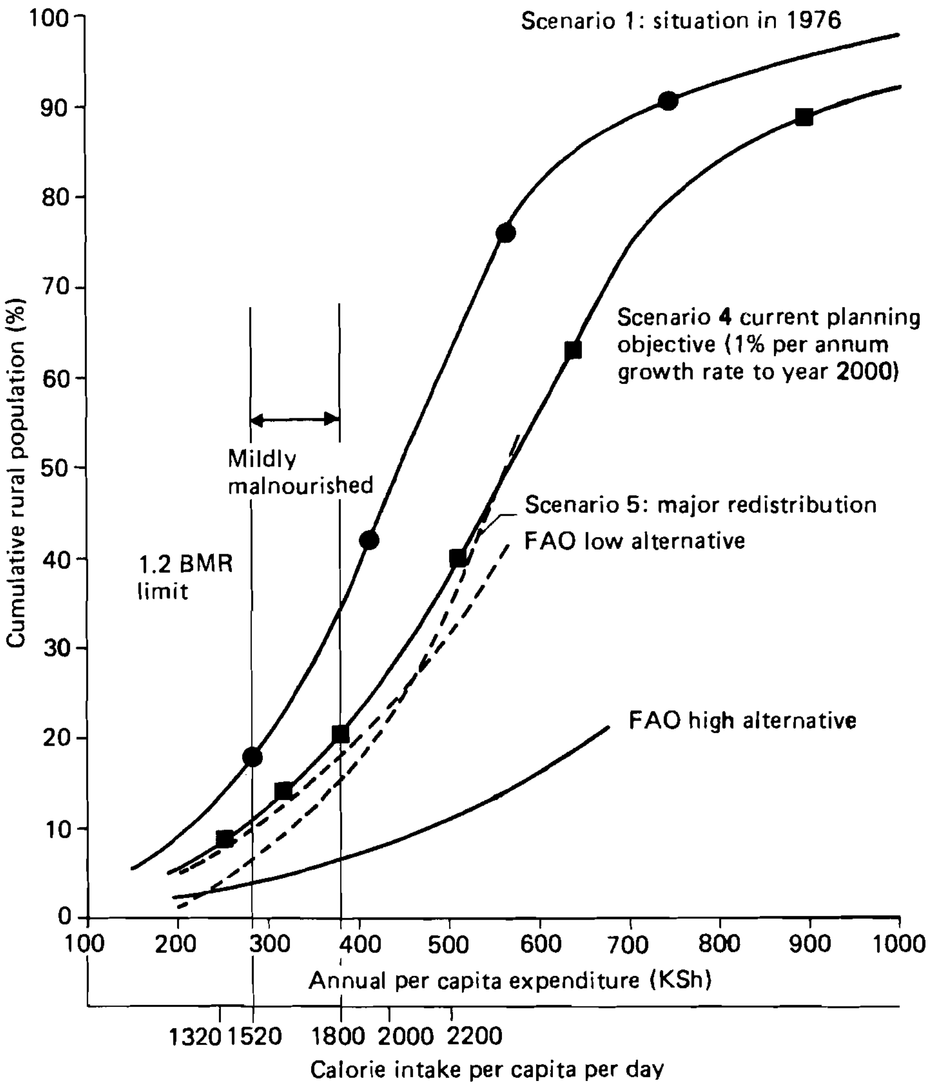

FIGURE 4 Impact of income distribution changes on calorie intake for rural Kenya.

below 1800 calories (the mild to moderate PEM threshold) falls from 33% to 15% and the proportion below 1.2 BMR falls from 17% to 6.5%.

This redistribution mechanism would not benefit the urban poor, who are in a (nominally) higher income bracket, but they could be included by suitable modification of the program.

6.2.8 Scenarios Compared

Scenario 1. The cumulative curves in Fig. 3 give the best indication of the effect of redistribution. The results are summarized in Tables 41 and 42. Note that currently 33% (4.29 million) suffer from malnutrition and that of these there are 2.19 million, 16% of the population, below the 1.2 BMR level.

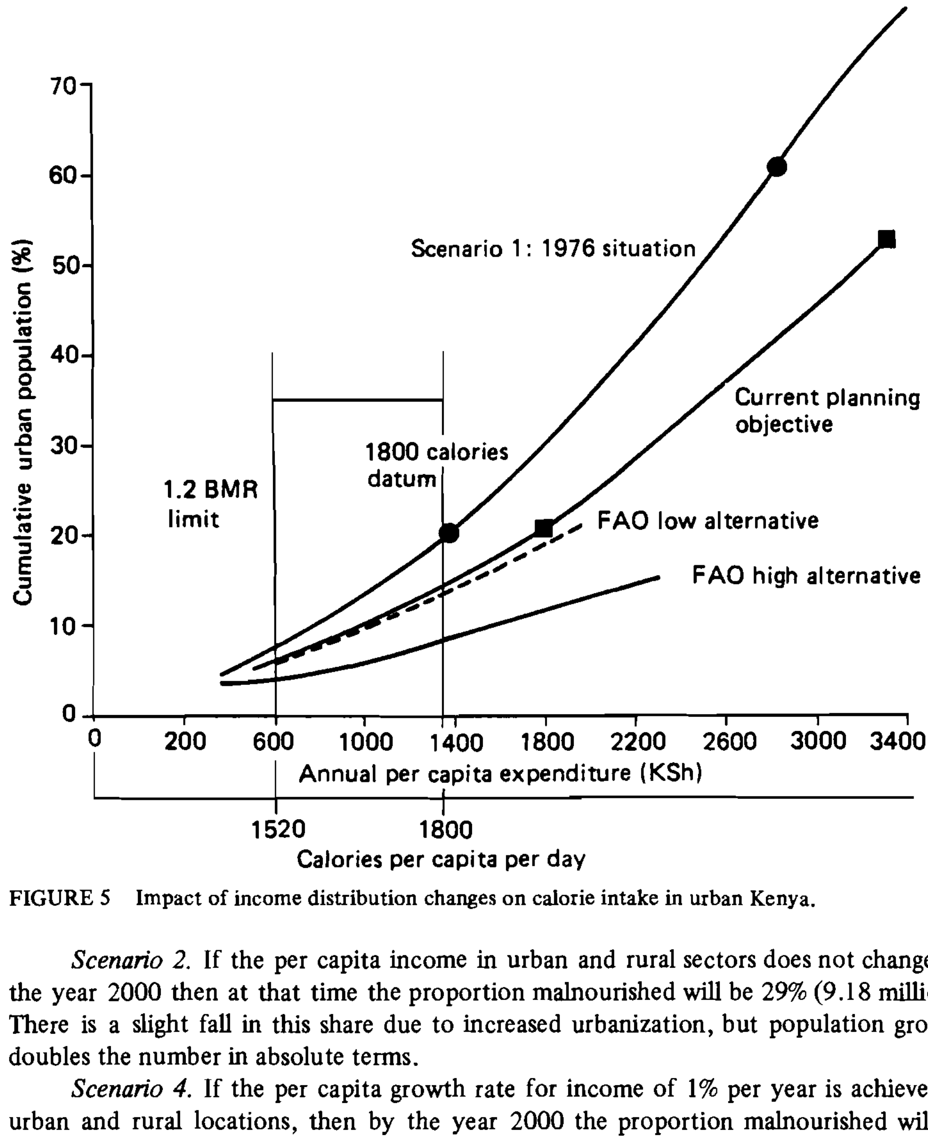

FIGURE 5 Impact of income distribution changes on calorie intake in urban Kenya.

Scenario 2. If the per capita income in urban and rural sectors does not change by the year 2000 then at that time the proportion malnourished will be 29% (9.18 million). There is a slight fall in this share due to increased urbanization, but population growth doubles the number in absolute terms.

Scenario 4. If the per capita growth rate for income of 1% per year is achieved in urban and rural locations, then by the year 2000 the proportion malnourished will be 18% (5.73 million) with 3.01 million or 10% below 1.2 BMR. This is a significant improvement in the percentage measure, but in absolute terms it is rather poor owing to the population growth.

Scenario 5. The impact of income redistribution is evident; in the rural areas the proportion malnourished falls from 33% to 9%, but even more striking is the change in those below the 1.2 BMR level, where there is a fall from 17% to 6.5%. For a normal healthy population one would expect a figure of around 2%.

Scenario 6. This is the FAO low alternative, but it still postulates an average per capita expenditure gain of 37% by the year 2000. The impact would be slightly better than the current planning objective, with an estimated 2.62 million people, or 8.4% of the population, below the 1.2 BMR datum by the year 2000.

TABLE 41 The impact of different scenarios on malnutrition by the year 2000.

Scenario	Mild to moderate PEM (1400–1800 calories per capita per day)	Severe PEM (less than 1400 calories per capita per day)	Total malnourished (less than 1800 calories per capita per day)
Current situation			
Rural			
Per cent	25	8	33
Millions	2.98	0.95	3.93
Urban			
Per cent	15	5	20
Millions	0.27	0.09	0.36
National			
Per cent	24	8	31
Millions	3.25	1.04	4.29
Scenario 4: without income growth			
Rural			
Per cent	25	8	33
Millions	5.68	1.82	7.50
Urban			
Per cent	15	5	20
Millions	1.26	0.42	1.68
National			
Per cent	22	7	29
Millions	6.94	2.24	9.18
Scenario 4: current policy			
Rural			
Per cent	11	5	16
Millions	2.50	1.14	3.64
Urban			
Per cent	9	3	12
Millions	0.76	0.25	1.01
National			
Per cent	10.5	4.5	15
Millions	3.26	1.39	4.65
Scenario 5: income redistribution			
Rural			
Per cent	8	1	9
Millions	1.82	0.23	2.05
Urban			
Per cent	9	3	12
Millions	0.76	0.25	1.01
National			
Per cent	8	2	10
Millions	2.58	0.48	3.06

TABLE 42 The impact of different scenarios on caloric intake by the year 2000.

Population group	Kenya Case Study estimates				FAO estimates	
	Scenario 1: current situation	Scenario 2: urbanization[a]	Scenario 4: current policy to 2000[b]	Scenario 5: major redistribution	Scenario 6: FAO low alternative	Scenario 7: FAO high alternative
Percentage figures						
Malnourished, rural	33	33	20	15	17.5	6.5
Below 1.2 BMR, rural	17	17	11	6.5	9.5	4
Malnourished, urban	20	20	14	14	13.5	8
Below 1.2 BMR, urban	8.5	8.5	6	6	5.5	4
Population in millions						
Malnourished, rural	3.93	7.50	4.55	3.41	3.96	1.47
Below 1.2 BMR, rural	2.03	3.86	2.50	1.48	2.15	0.91
Total rural population	11.92	22.73	22.73	22.73	22.64	22.64
Malnourished, urban	0.37	1.68	1.18	1.18	1.13	0.67
Below 1.2 BMR, urban	0.16	0.72	0.51	0.51	0.46	0.34
Total urban population	1.83	8.42	8.42	8.42	8.38	8.38
Malnourished, total	4.30	9.18	5.73	4.59	5.09	2.14
Below 1.2 BMR, total	2.19	4.58	3.01	1.99	2.61	1.25
TOTAL POPULATION	13.75	31.15	31.15	31.15	31.02	31.02

[a]Real per capita incomes remain unchanged in urban and rural areas, but the total composition changes.
[b]1% growth per year in per capita income for both urban and rural dwellers.
The malnourished datum is 1800 calories per capita per day; 1.2 BMR is 1517 calories per capita per day.

Scenario 7. The FAO high alternative postulates an increase in average per capita expenditure of about 120%. Few countries have ever succeeded in approaching this figure and for Kenya it is extremely unlikely barring a major oil strike. Even then it is not clear that the economy could absorb the impact of a major oil strike. For the record, it is estimated that in this scenario the number below 1.2 BMR would be reduced to 1.25 million, or 4% of the population. Given that one might expect 2% of a normal healthy population to be in this category, this outcome would certainly be desirable, but again, this scenario is extremely unlikely.

The obvious difference between Scenarios 5 and 4, the number in the less than 1.2 BMR category, is due to the lump sum increase being far more effective for the extremely poor than a proportional change in their meager income. Supply should not be a constraint, as evidenced by the production analysis in Section 4.

In summary, steady income growth rates will significantly reduce the percentage in the mildly malnourished category, but for those in the severe category other more direct approaches, such as lump sum transfers, are needed to produce significant change. While removal of malnutrition is a desirable goal, government policy must also strive to satisfy other goals. Some of these may conflict to a degree, so that the policy maker is inevitably faced with assessing appropriate trade-offs.

6.3 Current Government Policy

Viewed in a broad context, the government of Kenya has three broad classes of policy tools at its disposal: monetary, fiscal, and exchange rate policy. With these they aim for (again at a general level) full employment, price stability and external balance. If all these were achieved, goals such as adequate nutrition for all would presumably follow. Currently it may be said that these goals are being achieved with only limited success, so inevitably we must consider whether the tools are being used as effectively as possible.

Contrary to numerous pronouncements on the subject, the rural sector, which includes the vast majority of the population, certainly does not appear to be receiving a reasonable share of the budget. Typical numbers are given in Table 43 for some categories.

TABLE 43 Selected per capita expenditure by province, in Kenya pounds.

Province	Curative expenditure on health (1974–78)	Recurrent expenditure (1973–74)
Nairobi	6.59	70.76
Central	0.50	9.69
Coast	0.97	13.07
Eastern	0.64	6.42
Northeastern	0.04	3.54
Nyanza	0.58	3.28
Rift Valley	0.34	8.84
Western	0.18	4.09

SOURCE: Bigsten (1977).

It appears that resources are strongly directed to the urban areas. The next question is whether this is justified. In terms of the impact on employment and welfare for the bulk of the population, this is evidently not so. Nor does it seem to be paying dividends in terms of the goal for the external balance. Coffee and tea continue to be the mainstay of exports, with a rather dismal export performance for the other sectors. This suggests that strong consideration should be given to reorienting investment toward rural areas. This would involve greater encouragement to agriculture and agrobased industries and a careful pruning of some of the current urban industries.

The Agriculture Ministry, for its part, should seek to encourage the smallholders. In particular, the extension service will have to play its part in ensuring the proper utilization of investments. The share of the Ministry of Agriculture in the current forward budget is more than 12%. If it succeeds in utilizing this, then a substantial improvement in rural welfare should be achieved*.

6.3.1 Recent Policy Initiatives

Recent trends suggest that by the year 2000 there should have been a considerable overall alleviation of poverty. Yet even at this late date many will still be malnourished. This situation may be improved by more direct approaches to the poverty problem. Historically, most policies in Kenya have had a strong production orientation. Such policies often have a fairly undesirable distributional impact, as the more advanced producers are generally better poised to take advantage of them.

The cold world of reality suggests that institutional change generally comes about slowly, so it is much more likely that conventional policies will be modified or reoriented than that major new policies will be introduced. It is interesting to note the response of the government to the dramatic shortfall in the 1979–80 maize crop. Their major policy change was to increase the procurement prices for maize from KSh60 to KSh80 a bag.

Similarly, the plan (1979–83) emphasizes the strategy to be adopted for agricultural development toward the overall plan theme of "the alleviation of poverty". This development of agriculture includes the following initiatives:

- the government will have first option on the purchase of any areas of high potential land greater than 20 hectares offered for sale; this land would then be leased to landless families
- research and extension is to be oriented, with increased emphasis on smallholders
- there is to be an expenditure of K£71 million on small farm areas

The overall growth of employment in agriculture is projected as 2.7% per annum during the plan period, while rural employment is expected to grow at 3% per annum.

The overall share of agriculture in investment will not change very much. It is expected to remain at about 10% of the total while the manufacturing share will approach 20%. This is partly due to increased defense expenditure but also reflects the general feeling that returns on investment in other sectors, notably manufacturing, have simply been higher. This opinion has been much influenced by substantial costs overruns in recent

*The performance of the Ministry during the last few years suggests that they have not been able to utilize a substantial portion of the funds allocated to them.

irrigation schemes. Given the desire of decision makers to favor manufacturing, it seems that a compromise might be to tilt toward food and agrobased industries. If these could also be located in rural areas it would in addition have the socially desirable effect of moderating the urbanization process.

There is another whole set of policies that might loosely be termed consumption policies. In the few months after he took office President Moi proposed a number of interesting initiatives that seemed to signal a major shift in policy making. Notable among these are his pronouncements on literacy, school fees, free milk in schools, and land ownership.

6.3.2 Recent Initiatives for Consumption Policies

The impact on purchasing power of these programs will be strongly progressive and more immediate than anything that may result from the trickle-down effect of more conventional (in Kenya that is) policies.

It has been proposed to abolish school fees forthwith. In Section 3 it was indicated that the smallholders, even at the lowest income levels, strove to achieve some minimum cash level before increasing even food intake above the minimum level. In many instances much of this cash expenditure was for school fees. This policy would in fact be a direct transfer to these groups, and would either release cash for other needs or permit them to retain more of their food production for home consumption. Similarly with the milk program: each school child in standards one to six would be given a free ration*.

It is expected that small-farmers will meet much of the increased demand, but the marketing and storage facilities need considerable improvement.

The campaign aimed at literacy for all by 1983 should be a beneficial enabling investment. It should help to create greater awareness, to bring smallholders together and generally to facilitate the efforts of various agencies such as the extension service to improve their performance.

The overall thrust of the present plan is a greater emphasis on human development and the fulfilment of so-called basic needs. Some of the goals are given in Table 44: food and nutritional intake levels are considered a key measure of the overall planning operation.

Employers have now been directed to increase their work force by 10%. Since this is expected to be accomplished without complete wage constraints, the net effect on income distribution should be progressive.

In addition there is the issue that perhaps evokes strongest feelings among Kenyans – land. This was the issue at the core of the struggle for independence, and it continues to simmer at the front of the sociopolitical scene. Many landless still aspire to their own plot, but it is not clear that this will be physically possible. Some preliminary populist pronouncements indicate that the distribution of land should not deteriorate, and to underline this certain beach areas near Mombasa will be given back to the public.

6.4 Conclusion

The general conclusion is that, with appropriate policies, sufficient food from domestic resources should be available by the year 2000 to feed the expected population at that time of about 30 million people.

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*This program has since been contracted owing to food shortages resulting from inclement weather and a deterioration in the balance of payments.

TABLE 44 Basic needs targets[a].

Target	1976	1983	Measurement
GDP at market prices	1429	2194	K£ million (1976), 6.3% growth rate
GDP per capita	103.9	125.6	K£ (1976)
Inflation	16%	6.8%	Annual rate, GDP
Population	13,752,000	17,470,000	Based on a 3.5% growth rate
Population growth rate	3.5%	3.5%	This may be slightly higher
Crude birth rate	49.0	46.5	Births per 1000 population
Employment			
Modern sector	915,000	1,250,000	
Rural	4,045,000	5,140,000	
Urban informal	125,000	195,000	
Total	5,085,000	6,585,000	
Employment as percentage of labor force	90.6	92.2	
Education (1978–84)			
Rural literacy, population over 15	65% M, 31% F	100% M, 100% F	Ability to read in any language
Primary	3,135,000	3,825,000	Total enrolment
Secondary (government aided)	133,000	157,000	Form 1 to 6 includes vocational, agricultural, commercial
Harambee Institutes of Technology	1007	3859	
Harambee other than Institutes of Technology	190,799	233,000	Assisted and aided, including church and private
Technical	6480	8424	
Polytechnic	3282	4185	
Special education	3619	9629	
University	6250	8900	
Health care			
Hospitals	64	70	Government hospitals – province and district
Health institutions	761	806	Government hospitals, health centers, and subcenters, dispensaries
Doctor density	10.3	11.9	Number per 100,000 population
Registered and enrolled nurses density	95	110	
Access to health centers – rural	11%	12%	Households less than 2 km distant
Malaria	250,000 (1977)	150,000	Number of cases
Water[b]			
Rural holdings	44%	60%	Holdings with water
Rural access to water	11%	8%	Over 2 km to water service

TABLE 44 *Continued.*

Target	1976	1983	Measurement
Housing			
Rural[b], number of permanent structures	27%	30%	Dwellings with corrugated roofs
Dwellings with more than two rooms	48%	52%	
Houses with electricity	1%	1.2%	
Urban			
Number of units planned		13.6	Thousands per annum
Number of plots serviced		5.6	Thousands per annum
Foods[c]			
Calories intake	2070	2220	Per capita per day
Protein intake	57	65.5	Grams per capita per day
Mildly malnourished	30%	22%	Children aged 1–4 years
Severly malnourished	5%	2.5%	Children aged 1–4 years
Rural impoverished	40%	33%	Household income less than K£120 (1975) per year
Infrastructure			
Rural access to –			
Cooperative store	18%	21%	Less than 2 km
Market	38%	47%	Less than 2 km
Duka	64%	70%	Less than 2 km
Bus	46%	51%	Less than 2 km to public bus route
Matatu	61%	67%	Less than 2 km
Primary school	68%	72%	Less than 8 km
Secondary school	54%	60%	Less than 8 km
Telephone	1.01 (1978)	1.52	Per thousand population
Security			
National social security fund	1,028,000	1,333,000	Number of employees registered

[a]This is a selection of targets and is not meant to be exhaustive.
[b]Based on data from Integrated Rural Survey 2, 1976–77. This survey covered rural smallholders and the rural nonagricultural population, who are estimated at 11.7 million or about 80% of the total population.
[c]Based on Integrated Rural Survey 1, 1974–75. This survey covered rural smallholders and represents a population of about 10 million. Parts of the Rift Valley were somewhat underrepresented.
SOURCE: Development Plan 1979–83.

Increased production will mainly be achieved through higher yields as opposed to increasing the land area cultivated by irrigation and drainage. This effort needs to be complemented by an extension service oriented more toward smallholders to help channel the required inputs and expertise. This could be further helped by reorienting investment toward agriculture and rural industry.

Income distribution will be changed to some extent by urbanization and higher productivity. There will still be sharp urban–rural differences and the distribution within each sector will remain skewed. The inequalities will be gradually reduced, resulting in about 18% of the population suffering from protein energy malnutrition at that time, and still including 10% below 1.2 BMR rather than the 2% that would be expected in a normal healthy population. This is not a very encouraging prospect for the year 2000. These figures could be reduced to 15% and 6.5% respectively by the direct transfer of income to the poorest. Such a dramatic change would require a major reorientation of national policies. This suggests that the potential exists for Kenya in the year 2000 to be a much more egalitarian country than could have been anticipated from policy trends in recent years.

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APPENDIX: The Gini Coefficient

The Gini coefficient is a measure frequently used as an indicator of income inequality. The coefficient is computed from a Lorenz curve obtained by plotting the cumulative share of the population on the horizontal axis and the corresponding cumulative share of total income on the vertical axis. A typical Lorenz curve ABC is shown in Figure A1. This

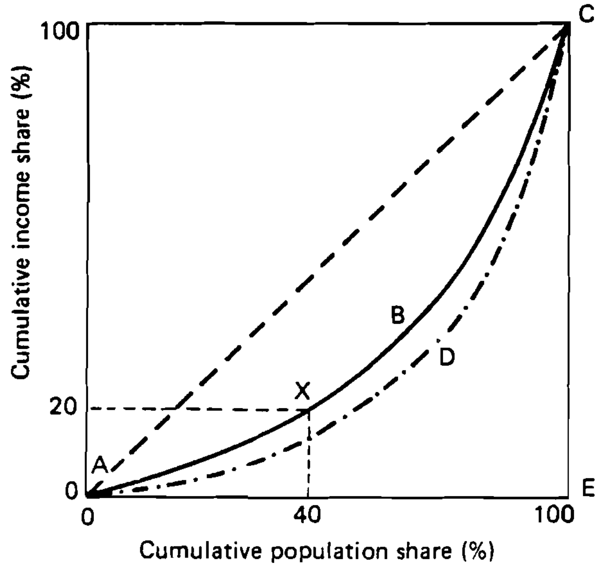

FIGURE A1 Income distribution in Kenya.

curve may be interpreted as follows. The point X on the curve indicates that the lowest earning 40% of the population receives 20% of the total income. If income were distributed absolutely equitably then the corresponding Lorenz curve would be the diagonal AC. For the limiting inequitable distribution the Lorenz curve would be AEC. This latter case would correspond to the situation where all but one of the population had zero income while one person received the entire income. A population with Lorenz curve ADC would have greater inequality in its income distribution than one with the curve ABC.

The Gini coefficient, then, is the ratio of the area between the curve and the diagonal (ABCA) to the area of the triangle AEC. Thus the Gini coefficient can vary in principle from zero (absolute equality) to unity (complete inequality). For most countries the Gini coefficient lies between 0.4 and 0.6.

It should be emphasized that the Gini coefficient is simply one summary statistic of income inequality and should be interpreted with caution.

MODELS FOR ANALYZING AGRICULTURAL NONPOINT-SOURCE POLLUTION

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SUMMARY

Mathematical models are useful means of analyzing agricultural nonpoint-source pollution. This review summarizes and classifies many of the available chemical transport and planning and management models. Chemical transport models provide estimates of chemical losses from croplands to water bodies; they include continuous simulation, discrete simulation, and functional models. A limited number of transport models have been validated in field studies, but none has been tested extensively. Planning and management models, including regional impact, watershed planning, and farm management models, are used to evaluate tradeoffs between environmental and agricultural production objectives. Although these models are in principle the most useful for policy-making, their economic components are much better developed than components for predicting water pollution.

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1 INTRODUCTION

The management of agroecosystems is usually for productive purposes. Land resources are subjected to meteorological inputs and management practices to yield desired biological outputs of food and fiber. The "desired" outputs and necessary management practices are determined by policy decisions of national and regional authorities and farm operators. These decisions may be mixtures of tradition, rational planning, and responses to economic stimuli. Regardless of their origin, however, agricultural policies are shaped primarily by their perceived effects on food and fiber production.

Twentieth century agricultural planners have learned that chemical inputs to crop production, in the form of fertilizers and pesticides, can be highly efficient means of increasing yields. In additon, the control of water inputs through irrigation has become a major factor in the conversion of arid regions to productive farmlands. Unfortunately, the agricultural policies which have encouraged irrigation and chemical use have not only increased efficiency, but have also produced distributions of chemical residuals in the environment that have degraded water quality. These water pollution impacts are largely unintentional. On nonirrigated land they are associated with diffuse or nonpoint sources that are caused by natural hydrologic phenomena. With irrigated agriculture, nonpoint-source pollution is often caused by return flows that carry the leaching waters necessary to maintain favorable salt balances for crop growth.

When the water quality problems caused by agricultural nonpoint sources become severe, production practices may need to be evaluated for both their economic and environmental consequences. As the control of agricultural pollution has relatively recent emphasis even in developed countries, past experience provides little assistance, and it has been necessary to rely on mathematical models as tools for policy evaluation.

Models have been developed for two major purposes. The first is the estimation of the water pollution impacts of agricultural production and pollution control practices. The second is the analysis of tradeoffs between agricultural production and environmental quality objectives.

A large number of nonpoint-source models have been constructed and are now available for agricultural and water quality planners. These models vary significantly in structure, underlying assumptions, and purpose. This diversity is due larely to the pressing need to resolve policy issues related to agricultural pollution. Modeling research has often been problem-oriented, and there has been little time for the long-term investigations that are necessary for the orderly development of scientific theory. Rather, engineers and scientists from different disciplines responded to urgent needs with models which are capable of providing some of the more critical information required for rational policy-making.

This report is a review of these first-generation agricultural nonpoint-source models and has two broad objectives: (1) to organize the immense variety of models into a framework, or system of classification which can usefully highlight significant model differences and similarities; and (2) to summarize model characteristics which are likely to be of interest to potential users; i.e., to provide a catalogue or a user's guide to the state-of-the-art. The review is largely descriptive and does not critically evaluate the mathematical characteristics of the models; however, it attempts to provide a current assessment of modeling directions.

The report is divided into three sections. The first is devoted to chemical transport models. These are models designed to predict the losses of salts, nutrients, and pesticides from agricultural lands. Such models can in principle be linked to water quality models which estimate the effects of transported chemicals on water quality. Water quality models are not unique to nonpoint sources since they are in general designed to predict the response of a water body to both point and nonpoint sources. The literature contains many examples of such models and they are omitted from this review. Sediment transport models are also omitted, partly in the interest of brevity, but also as a reflection of the fact that sediment *per se* is seldom a critical or manageable water quality problem. Sediment is important mainly as a carrier of chemicals, and sediment models are integral components of many chemical transport models. The second section of the report is devoted to planning and management models for agricultural pollution. Most of these are linear programming models which are used to analyze the environmental and economic impacts of nonpoint-source controls. The final section concludes and suggests possible directions for future modeling research.

2 CHEMICAL TRANSPORT MODELS

The major hydrologic processes which transport chemicals from cropland to surface or groundwater bodies are shown in Figure 1. Omitted from the figure are atmospheric interactions whereby volatilized chemicals or aerosols are transported to surface waters. The significance of such air-borne pollution is largely unknown, and there have been few attempts to model these phenomena. The hydraulic components of nonpoint-source pollution are surface runoff, subsurface runoff (interflow), and percolation. The latter two flows can transport dissolved chemicals while surface runoff may carry both dissolved and solid-phase (particulate) chemicals. Solid-phase chemicals travel with sediment that has been eroded from the land surface and carried by surface runoff. Transport models may be designed to predict losses of chemicals from the land surface and soil in one or more of the possible water components. Relatively few models are capable of complete description of all of the transport pathways.

2.1 Model Types and Characteristics

There are obviously many different ways of classifying a subject as broad and fragmented as nonpoint-source models, and the system proposed here is preliminary and somewhat arbitrary. In general, the system was designed to capture the significant differences and similarities among models and provide summary information to potential users. In addition, the method of classification was constrained by the need to accommodate the 37 widely varying chemical transport models which are included. The models are described by six general characteristics:

1. Model Structure Type
2. Principal Outputs
3. Scale
4. Time Step
5. Calibration
6. Validation Studies

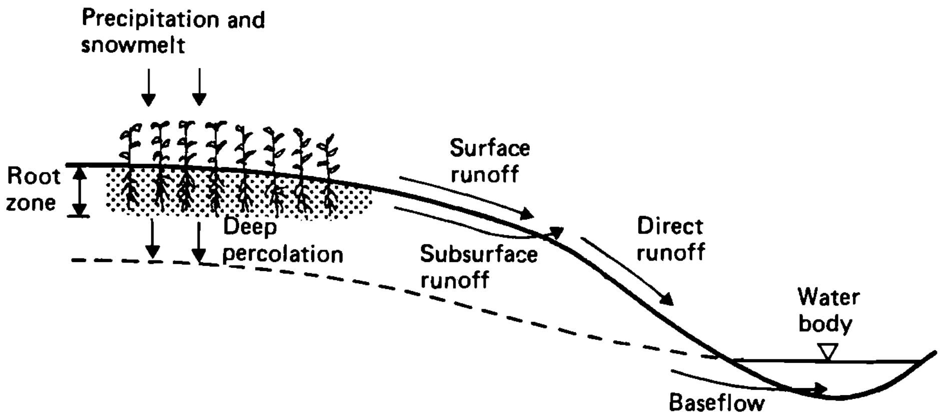

FIGURE 1 Transport processes for nonpoint-source pollution.

2.1.1 Model Structure Type

There are different types of chemical transport models. The first, and most analytical, are continuous simulation models. These models are based on either systems of partial differential equations for water and solute transport or on kinetic models described by ordinary differential equations. The second are discrete simulation models. Such models are sets of algebraic equations which describe discrete changes over time. Because the models are solved algebraically they are typically easier to manipulate than continuous models. The simplest transport models, which can be classified as functional models, differ from simulation models in that they seldom attempt to capture the details of the actual biological, chemical, or physical processes which affect chemical losses. Rather, they are simple equations which predict chemical losses based on intuitive or empirical information.

2.1.2 Principal Outputs

This model characteristic is largely self-explanatory, and accounts for many of the significant differences in models. Models are described by both the chemicals they portray – salts, nitrogen (N), phosphorus (P), or pesticides – and the hydraulic distribution of chemical losses – surface runoff, subsurface runoff, percolation.

2.1.3 Scale

Scale refers to assumptions of spatial homogeneity. Field models assume that the soil surface is horizontally homogeneous, thus they are applicable to a single "field" with a uniform soil type. Watershed models can be used to describe heterogeneous drainage areas, and in particular the distribution of chemical sources from different fields and their aggregation for an entire watershed.

2.1.4 Time Step

Model time step is an important characteristic for potential users, since it is an indicator of computational and meteorologic data requirements. Model computations must be repeated for each time step, and hence models with small time steps are often more costly to use.

2.1.5 Calibration

Calibration involves the use of a model to estimate its own parameters. In general, a model must be calibrated if, in applying the model to a specific physical setting (field or watershed) it is necessary to measure phenomena which the model is designed to predict. The purpose of the measurements is to provide values for model parameters which would otherwise be difficult, if not impossible to estimate. Calibration is a complex issue in nonpoint-source modeling and involves both practical and philosophical considerations which are both fundamental and somewhat subjective.

The process of calibration can be considered a rational response to uncertainty. No transport model for agricultural chemicals can be more than a crude approximation of reality. By providing for calibration, the modeler can include mathematical descriptions of processes whose parameters defy simple evaluation based on commonly available soil, crop, or chemical properties. In addition, by calibrating a model to a monitored situation, greater predictive accuracy may be obtained. Although this argument is in principle correct, it must be recognized that the calibration process may mask model limitations. When the physical and chemical processes within a model are described by analytical relationships based on generally accepted scientific theory, the adjustment of several parameters by calibration may be a sound procedure. Unfortunately, calibration parameters sometimes do not correspond either to rational analytical relationships or recognizable physical or chemical properties of the transport processes. In this case, calibration may be an arbitrary scaling of model predictions to force an otherwise inadequate model to yield reasonable results.

Most calibration needs fall somewhere between the two extremes, and the classification system used in this report does not attempt to evaluate the degree to which a model may be compromised by calibration. To some extent, any such assessment would be subjective. However, it is apparent that any need for calibration imposes constraints on a model's general applicability. Agricultural nonpoint-source models must be used ultimately to evaluate management practices, and one can seldom guarantee that changes in management from a calibrated situation will not change the calibrated parameters. Furthermore, since models requiring calibration cannot be applied to unmonitored sites, they are of limited usefulness in studies where resources do not permit such monitoring.

As a final point, it should be noted that in spite of the problems caused for potential users, a model's need for calibration is not necessarily a negative attribute. A calibrated model may provide a more realistic description of chemical transport than an alternative model which has no calibration parameters. Difficulties in measurement of parameters may not imply that a model is unscientific. In addition, increased experience in applying a model may lead to simpler means of parameter estimation. In this fashion, experience may eliminate the calibration requirement.

2.1.6 Validation Studies

A complete discussion of model validation is well beyond the scope of this report, and in the present context this classification category refers only to whether or not there has been a documented attempt to determine the accuracy of a model's predictions by comparison with measured chemical transport losses. Such an evaluation must be at the intended scale of the model (field or watershed rather than laboratory) and be based on different measurements than those used for calibration. Given the unavoidable errors in the collection and analysis of chemical losses from croplands and uncertainties in model parameter estimates, it is difficult to see how any transport model can ever be shown to be "valid." Thus, the comparison of model predictions with observations is largely subjective. Nevertheless, these comparisons provide the only quantitative indicator of the validity of a model as an abstraction of reality. Many chemical transport models have not been subjected to such testing and hence are not yet suitable as general tools for either estimating agricultural pollution or evaluating management practices.

2.2 Continuous Simulation Models

Chacteristics of 13 simulation models are listed in Table 1. Model time steps are not provided since all the models are based on differential equations and can be solved analytically or numerically for arbitrary time increments. With two exceptions (Amberger et al., 1974; Konikov and Bredehoeft, 1974), all the models are limited to percolation losses from a field and/or groundwater transport in a watershed (aquifer).

TABLE 1 Continuous simulation models for agricultural chemical transport.

Reference	Principal output	Scale	Calibration required?	Validation studies?	Model structure
Davidson et al. (1978) ("Research Model")	N in percolation	Field	Yes	No	One-dimensional D'Arcy flow and convection/dispersion partial differential eqns.
Davidson et al. (1978) ("Management Model")	N in percolation	Field	No	Yes	"Piston displacement" of water, 1st order kinetics for N
van Veen (1977)	N in percolation	Field	Yes	Yes	No water model, ordinary differential eqns. solved by CSMP
Mishra et al. (1979)	P in percolation	Field	Yes	Yes	No water model. 1st order kinetic eqns. solved by CSMP
Shah et al. (1975)	P in percolation	Field	Yes	Yes	One-dimensional D'Arcy flow and convection/dispersion partial differential eqns.
Mansell et al. (1977b)	P in percolation	Field	Yes	No	One-dimensional convection/dispersion partial differential eqns. No water model.
Mansell et al. (1977a)	P in percolation	Field	Yes	No	One-dimensional convection/dispersion partial differential eqns. Kinetic models for exchange of P forms. No water model.
O'Connor et al. (1976	Pesticide in percolation	Field	Yes	No	One-dimensional convection/dispersion partial differential eqns. No water model.
Davidson et al. (1975	Pesticide in percolation	Field	Yes	Yes	One-dimensional D'Arcy flow and convection/dispersion partial differential eqns.

Amberger et al. (1974)	N in percolation, P in surface runoff	Field	Yes	No	Differential eqns. for water and N movement. Erosion modeled and all P losses assumed solid-phase. Solution by CSMP. No model testing.
Czyzewski et al. (1980)	N in percolation and groundwater	Watershed	Yes	No	Two-dimensional D'Arcy flow and convection/dispersion partial differential eqns. No model testing.
Konikow and Bredehoeft (1974)	Salts in return flows, river and groundwater	Watershed	Yes	Yes	Conjunctive aquifer and river model. Two-dimensional. D'Arcy flow and convection/dispersion partial differential eqns. for groundwater, simple mass balance for river.
Mercado (1976)	N, salts in percolation and groundwater	Watershed	Yes	No	Treats aquifer as single cell with complete mixing. Analytical solution to 1st order equation.

Ten of the models are field-scale models designed to predict vertical movement of soil chemicals in percolation waters. Six of the ten models are based on the general convection/dispersion equation for transport of a reactive solute in a porous medium and are a sample of many comparable models that have appeared in the literature. The "research model" of Davidson et al. (1978) is the most complete of these models, providing detailed analytical descriptions of N sources, sinks, and transformations as well as a complete water balance. The model is difficult to solve and is very data intensive. Although the three models developed by Shah et al. (1975) and Mansell et al. (1977a, 1977b) are designed for similar purposes, only the first incorporates a water flow component and has been subjected to validation studies. Similarly, the two pesticide models (O'Connor et al. 1976; Davidson et al. 1975) are both designed for estimating percolation losses, but only the latter includes a water model and has been tested in validation studies.

As a generalization, models for chemical losses that are based on convection/dispersion equations must be calibrated and are not easily verified. When such models incorporate water balances they are difficult to solve for realistic boundary conditions. The rationale for this modeling approach has been that it is a fundamental and hence realistic theory for chemical movement through the soil. This view has been challenged by Sposito et al. (1979):

> . . . none of the existing foundation theories has yet achieved the objectives of: (1) deriving, in a physically meaningful and mathematically rigorous fashion, the macroscopic differential equations of solute transport theory, and (2) elucidating the structure of the empirical coefficients appearing in these equations.

However, these same general objections are applicable to any chemical transport model, and they are not sufficient reasons for rejecting the convection/dispersion approach.

Three of the continuous simulation models have structures somewhat similar to the discrete simulation models (Section 2.3). However, they are based on differential equations and are solved by the IBM Continuous System Modelling Program (CSMP). The van Veen (1977) and Amberger et al. (1974) models provide very detailed descriptions of soil N processes. Both models must be considered preliminary, since the former has yet to incorporate plant uptake of N and soil moisture balances and the latter has not been tested at any scale. The model developed by Mishra et al. (1979) for P transformations in forest soils is the most operational of the CSMP models since it is both relatively simple in structure and has been tested with validation studies.

The "management model" of Davidson et al. (1978) is a simplified version of their "research model" and provides a very straightforward means of estimating percolation losses of N. This model, which has been validated, is the only continuous simulation model that does not require calibration. Of all the models listed in Table 1, it is probably the only one which is currently suitable for a general user.

Two of the watershed models (Czyzewski et al., 1980; Konikow and Bredehoeft, 1974) are attempts to describe chemical distributions in aquifers. The Czyzewski model is intended for application to a large portion of the Skrwa River Basin in Poland. The model is preliminary at this time, and major programs of data collection and testing will be necessary to make it operational. Konikow and Bredehoeft's model links surface and groundwater flows and has been successfully applied to a portion of the Arkansas River in Colorado.

2.3 Discrete Simulation Models

The 19 simulation models listed in Table 2 fall into three groupings: percolation models, models based on complete hydrologic balances, and models for irrigation return flows.

2.3.1 Percolation Models

The first seven models are designed to estimate percolation losses of dissolved N from fields. One of the models (Dutt et al., 1972) is also capable of estimating salt losses. The models developed by Addiscott (1977), Haith (1973), and Saxton et al. (1977) are similar in that they are restricted to situations where runoff is either negligible or is provided as model input. Each of these models is based on relatively simple N balances and has modest data and computational requirements. Addiscott's model is the only one of the three that does not require calibration, although it has only been validated for nongrowing season conditions. The next two models (Duffy et al., 1975 and Tanji et al., 1979) are heavily empirical and have not been validated with data sets other than those used for calibration. Since both models require adjustment of many calibration parameters, they do not appear suitable for general use.

The final two percolation models are somewhat unique. The model for percolation N losses given in Stewart et al. (1976) has a complete hydrologic balance component including runoff, although it does not predict losses of N in runoff. This type of hydrologic model, based on the US Soil Conservation Service's (SCS) runoff equation, is similar to several models discussed in the next model group. The model does not require calibration, but has not been validated. The model of Dutt et al. (1972) was one of the first agricultural transport models. It is in many ways a hybrid, since it has a water flow component similar to the continuous simulation models. The time step of 0.1 da is somewhat misleading since portions of the model require iterative computations at much greater frequencies. In spite of its precedence over later models, it does not appear to have seen significant use, probably due to its extensive computational and data requirement.

2.3.2 Complete Hydrologic Models

Nine of the remaining models contain complete hydrologic budgets. Three models Frere et al., 1976; Tseng, 1979; Williams and Hann, 1978) are designed to estimate watershed chemical export in streamflow, and the latter two have been incorporated in watershed planning models. Watershed models differ from field models in that the former consider the variations in soils and crops in a large drainage area and integrate distributed chemical losses into a time series of total chemical mass fluxes from the watershed. Such an integration is extremely difficult and it is not surprising that only the simplest of the three models (Tseng, 1979) has been validated. The model of Williams and Hann is the most complete watershed model, although it does not include dissolved P losses.

The first four field-scale models (Haith, 1979; Knisel, 1980; Haith, 1980; Steenhuis, 1979) have similar hydrologic structure based on the SCS runoff equation. However, the Knisel and Steenhuis models have options permiting infiltration calculations based on the Green and Ampt infiltration equation at hourly time steps. The Cornell Nutrient Simulation (CNS) model (Haith, 1979) is a relatively efficient model that does not require calibration. Daily water balances are aggregated for the monthly nutrient submodel. The US

TABLE 2 Discrete simulation models for agricultural chemical transport.

Reference	Principal outputs	Scale	Time step	Calibration required?	Validation studies?	Model structure
Addiscott (1977)	N in percolation	Field	da	No	Yes	Separation of soil water into mobile and retained fractions. No runoff.
Haith (1973)	N in percolation	Field	mo	Yes	Yes	Analytical eqns. for mineralization and leaching. Regression eqns. for crop uptake. No runoff.
Saxton et al. (1977)	N in percolation	Field	da	Yes	Yes	Simple N model combined with more complex soil moisture model. No runoff.
Duffy et al. (1975)	N in percolation (tile flow)	Field	12 hr	Yes	No	Empirical eqns. for runoff and most N process in soil.
Tanji et al. (1979)	N in percolation	Field	yr	Yes	No	Water and N processes described by empirical linear eqns.
Stewart et al. (1976)	N in percolation	Field	da	No	No	Piston flow with exclusion factor. Nitrification is major N process. SCS runoff eqn.
Dutt et al. (1972)	N, salts in percolation	Field	⩽ 0.1 da	Yes	Yes (N)	D'Arcy one-dimensional water flow. N reaction rates based on regressions. No runoff.
Frere et at. (1975)	N, P, pesticde in streamflow	Watershed	hr	Yes	No	Based on USDA runoff model (Holtan et al., 1975).
Tseng (1979)	N in streamflow	Watershed	hr	Yes	Yes	Dissolved N. Based on USDA runoff model (Holtan et al., 1975). Watershed divided into hydrologic zones.

Williams and Hann (1978)	N, P in streamflow	Watershed	da	Yes	No	Solid-phase P, dissolved and solid-phase N. SCS runoff, USLE erosion. Stream routing functions, synthetic hydrographs.
Haith (1979)	N in total runoff and percolation, P in runoff	Field	da	No	Yes	Solid-phase and dissolved chemicals, SCS runoff USLE erosion. Synthetic hydrograph (peak flow).
Knisel (1980)	N, P, pesticide in total runoff and percolation	Field	da	No	No	Solid-phase and dissolved chemicals. SCS runoff eqn., synthetic hydrograph (peak flow). Multiparameter erosion/sedimentation model.
Haith (1980)	Pesticide in total runoff	Field	da	No	Yes	Dissolved and solid-phase pesticides. SCS runoff, USLE erosion.
Steenhuis (1979)	Pesticide in total runoff, percolation	Field	da	Yes	Yes	Dissolved and solid-phase pesticides. SCS runoff, USLE erosion.
Donigian et al. (1977)	N, P, pesticide in surface, subsurface runoff, base flow	Field	5–30 min	Yes	No	Kinetic models for soil chemicals. Stanford Watershed model for moisture balance, analytical erosion model.
Bruce et al. (1975)	Pesticide in runoff	Field	5 min	Yes	No	Empirical characteristic functions for runoff, sediment transport. Pesticide concentrations by regression. No pesticide decay.
Riley and Jurinak (1979)	Salts in return flows	Watershed	Steadystate	Yes	No	Simple salt balances based on measured river salinity.
Scherer (1977)	Salts in return flows and river	Watershed	Steadystate	No	No	Simple mass balances for water, salt in soils and river. No groundwater interactions.
Bardaie (1979)	Salts in return flows and river	Watershed	yr	Yes	Yes	Extension of Scherer (1977) model to predict changes over time in soil and river salinity.

Department of Agriculture CREAMS (Chemicals Runoff and Erosion from Agricultural Management Systems) model (Knisel, 1980) has many structural similarities to the CNS model and differs chiefly in its handling of erosion and sediment transport. The CREAMS model includes sediment detachment, transport, and deposition based on particle size distribution, while the CNS model estimates sediment losses by event-based modifications of the Universal Soil Loss Equation (USLE). The CREAMS model, which has not yet been validated, can in principle be used without calibration although many of its parameters, particularly those for sediment transport, are very difficult to estimate. The two pesticide models (Haith, 1980; Steenhuis, 1979) are similar in structure, but the Steenhuis model is unique in its ability to estimate the downward movement of pesticides in the soil.

Although the Agricultural Runoff Management (ARM) model developed by Donigian et al. (1977) produces output similar to the CREAMS model, it has very different hydrologic and sediment components. The model's foundation is the Stanford Watershed Model that determines outflow hydrographs from catchments based on a calibration approach for infiltration, subsurface runoff, and soil moisture capacities.

The final model in this category (Bruce et al., 1975) is completely empirical. It is designed to estimate pesticide losses during runoff events. It does not consider the dynamics of pesticide decay between events, and hence does not have the capabilities of the other pesticide models.

2.3.3 Irrigation Return Flow Models

There are a variety of models designed to analyze salinity problems for irrigated agriculture (see for example, the review by Walker, 1977). The three listed in Table 2 (Riley and Jurinak, 1979; Scherer, 1977; Bardaie, 1979; also described in Bardaie and Haith, 1979) are not necessarily typical, but unlike many other models, they are designed to evaluate both the magnitudes of salt fluxes in return flows and their effects on downstream diversions. Salinity models differ significantly from other nonpoint-source models in that they are concerned with conservative chemicals and well-defined drainage systems to transport leached chemicals to surface waters. Runoff prediction is usually not important, and model structures are based on simple mass balances for water and salinity.

2.4 Functional Models

The advantages and disadvantages of functional models for prediciton of chemical transport are relatively apparent. Functional models are useful since they provide answers with minimal computational effort and data requirements. As such, they have been important tools in providing the preliminary estimates of chemical losses needed to complete many of the early studies of agricultural nonpoint-source pollution. Unfortunately these advantages are mostly operational. Since functional models do not attempt to simulate the fundamentals of chemical transport processes, they may not be reliable bases for designing pollution control programs.

Characteristics of five functional models for chemical transport are given in Table 3. The Burns (1974, 1975) N percolation model is the simplest and perhaps most reliable of the models. It consists of a simple leaching equation that is capable of predicting the

TABLE 3 Functional models for agricultural chemical transport.

Reference	Principal outputs	Scale	Time step	Calibration required?	Validation studies?	Model structure
Burns (1974, 1975)	N in percolation	Field	Arbitrary	No	Yes	Downward movement of nitrate during nonplowing season. No water model.
Haith and Tubbs (1980)	N, P in rotal runoff	Field/ watershed	da	No	Yes	Runoff from SCS equation multiplied by dissolved concentrations, erosion from USLE multipled by soil concentrations.
Bogardi and Duckstein (1978)	P in surface runoff	Field/ watershed	da	Yes	No	Dissolved losses based on SCS runoff, solid phase losses from USLE.
McElroy et al. (1976)	N, P, pesticides in surface runoff	Field/ watershed	Steady state	No	No	Losses based on USLE erosion multiplied by concentrations. Watershed sediment delivery from drainage density.
Holy et al. (1980)	N, P in surface runoff	Field	Arbitrary	Yes	No	Runoff from free surface flow partial differential eqns. Sediment, nutrient fluxes from regressions.

downward displacement of N (nitrate) in the soil profile. The quantity of N available for movement and percolation volume must be known. Nitrogen sinks and sources are not considered explicitly. Haith and Tubbs (1980) have tested a functional model based on the SCS runoff and USLE equations. When applied to a watershed, nutrient losses are computed from each field and summed for estimates of watershed export. The model of Bogardi and Duckstein (1978) is similar, but is limited to phosphorus and requires calibration. Both models are event based; i.e., they compute losses for each runoff event.

The "loading functions" proposed by McElroy et al. (1976) are based on average annual sediment losses predicted by the USLE. Although these functions are reasonable only for solid-phase chemical losses and have not been validated, they have been widely used. Watershed losses are determined by multiplying aggregated field losses by sediment delivery ratio. The final model, proposed by Holy et al. (1980), is a hybrid. It contains a continuous runoff model consisting of the general partial differential equations for free surface flow. Conversely, nutrient and sediment fluxes in runoff are determined by regression equations. This model has yet to be tested, and the contrasting levels of detail in the runoff and nutrient components result in greater data and computational requirements than other functional models.

3 PLANNING AND MANAGEMENT MODELS FOR AGRICULTURAL NONPOINT SOURCES

Planning and management models are designed to analyze the economic implications of alternative policies or management practices for controlling agricultural nonpoint sources. This type of analysis is necessary for evaluation of tradeoffs between environmental and production objectives. Models are important because agricultural systems are usually too complicated for the impacts of environmental control policies to be readily apparent. Furthermore, the maintenance of agricultural productivity and/or income are usually of such importance that policy-makers are reluctant to implement new regulatory programs without documentation of economic impacts.

3.1 General Approach

Unlike chemical transport models, planning and management models are all basically similar. They are based on a budgeting approach which quantifies resource requirements, financial benefits and costs, and other relationships between agricultural management activities. Budgeting is frequently within the context of optimization and most planning and management models are solved by linear programming (LP). The different types of studies can be illustrated by the general LP model:

$$\text{Max/Min } Z = \bar{c}\bar{X} \quad (1)$$

$$\bar{\mathbf{A}}\bar{\mathbf{X}} = \bar{b} \quad (2)$$

$$\bar{\mathbf{X}} \geqslant 0 \quad (3)$$

In this model $\bar{X}$ is a vector of agricultural management practices which can include crop/soil combinations, chemical applications, livestock numbers, etc. Costs or returns $\bar{c}$ are asssociated with the activities, and the relationships between activities are indicated in eqn. (2), where $\bar{A}$ is a matrix of activity coefficients and $\bar{b}$ a vector of resource or other physical limits.

This type of optimization model can be manipulated in several ways to explore the impacts of pollution control measures on costs or income, Z:

1. The constraint set (eqn. 2) can include budgeting of pollutant losses resulting from each activity. The associated right-hand side constants (elements of $\bar{b}$) are upper limits of total pollutant losses. These constants can be progressively tightened to determine changes in total income or costs, Z.
2. Activities can be added to or subtracted from $\bar{X}$. For example, certain pesticides may be banned and new tillage practices added.
3. Characteristics of activities, which affect pollutant losses, can be changed. For example, the fertilizer application associated with a particular crop may be reduced. Such changes will modify certain of the coefficients in $\bar{A}$.
4. The costs and returns associated with certain activities can be modified to reflect subsidies or taxes, offsite damages (e.g., damages to a downstream irrigator due to saline return flows), or onsite benefits (e.g., improved soil productivity with erosion control).

3.2 Characteristics of Modeling Applications

The 19 planning and management models which are summarized in this paper fall into three distinct groups. Regional impact models are designed for macroscale evaluation of the impacts of environmental and agricultural management policies on crop distributions, farm and consumer prices, and income and other aggregated economic measures. These models cover large geographic areas and usually must consider (sometimes only implicitly) supply and demand relationships. Watershed planning models are applied in the context of specific water quality problems such as reservoir eutrophication or sedimentation. The objective is to develop a comprehensive program for control of agricultural practices and point sources, if necessary, to efficiently meet water quality objectives. The third group is farm management models that are designed to evaluate the impacts of pollution control on the income and management practices of an individual farmer.

Within each group, the modeling studies are summarized with respect to five characteristics:

Environmental emphasis

The most common modeling application is to sediment control, primarily because of the availability of simple sediment models (the USLE and sediment delivery ratios) that are easily incorporated into optimization models. However, other environmental pollutants that have been studied are pesticides, nutrients, and salinity.

Location

Unlike the chemical transport models, planning and management models have little identity beyond specific applications. Hence most of the latter models have been tested in actual locations.

Optimization technique

Those models which incorporate optimization are solved by either linear programming or dynamic programming (DP).

Method for pollution estimation

In several cases, the models contain no direct estimates of pollution. More commonly, estimates are based on the USLE or simple functional chemical transport models. The most interesting and realistic models contain pollutant loss estimates based on discrete simulation models. In these situations, a two-phase modeling procedure is followed in which simulation is used to generate chemical transport data, and management programs are selected by an optimization model.

Policy implications

Planning and management models have little intrinsic value and are useful only to the extent that they provide information for policy-making. Hence this model characteristic, which summarizes the relevant information produced by the model applications, is probably the most relevant indicator of the value of a particular modeling study.

3.3 Regional Impact Models

Application of regional planning models are summarized in Table 4. The four applications are modifications of two large LP models that describe either the entire US agricultural sector or the cornbelt states. In the first of these applications (Heady and Vocke, 1979) a national model of 105 producing, 51 water supply, and 28 market regions was used to evaluate effects of restrictions on cropland erosion and N fertilizer applications. The transport of eroded soil or N to waterways was not included, so no evaluation of water pollution was made. Erosion restrictions were imposed limiting soil loss from each land type to levels that would maintain soil productivity. Nitrogen fertilizer applications were constrained to 55 kg/ha. As indicated in Table 4, although the restrictions have little national impact, regional changes can be severe, since soils in some regions are much more subject to erosion than those in other regions.

The second national application (Wade and Heady, 1978) involved a more sophisticated application of the large model used by Heady and Vocke. The model was modified to include not only erosion estimates, but also methods for transporting the eroded soil to streams and subsequent entrapment of the sediment in reservoirs. Sediment fluxes were estimated in the 18 major US river basins. Wade and Heady's model is the only one of the four models in Table 4 that is capable of directly estimating water quality impacts (sediment fluxes, in this case). Two types of constraints were investigated: restrictions on sediment fluxes in each basin and restrictions on farm level erosion similar to those in Heady and Vocke (1979). A general result of the study was that uniform controls on

TABLE 4 Application of regional planning models to agricultural nonpoint source pollution problems.

Reference	Environmental emphasis	Location	Optimization procedure	Method of pollution estimation	Policy implications
Heady and Vocke (1979)	1. Erosion 2. N fertilizer	Entire US	LP	USLE	1. Uniform restriction on soil loss and fertilizer use will have modest effects on national prices and production value. 2. Large regional shifts in crops and farm income will be produced.
Wade and Heady (1978)	River sediment fluxes	Entire US	LP	USLE. sediment delivery ratios, reservoir entrapment.	1. Minimizing cropland sediment contributions increases aggregate commodity costs 42%. 2. Erosion control at farm level produces different results (distributions of costs and sediment) than restrictions on river basin sediment loads.
Taylor and Frohberg (1977)	1. Erosion 2. Insecticides 3. Herbicides 4. N fertilizer	US cornbelt	LP	USLE	1. Extreme restrictions on chemical use (banning pesticides, reducing N fertilizer) have more adverse effects on consumers than farmers. 2. Soil loss taxes have little effect on commodity prices but decrease farm income sharply.
Seitz et al. (1979)	Erosion	US cornbelt	LP	USLE	1. Aggregate impacts of soil erosion control on farm income are small. 2. Selective erosion controls in one cornbelt state but not others affect crop distributions among states, but cause little change in farm incomes in each state.

farmland erosion are relatively expensive means of reducing river sediment loads since they are not limited to cropland that is most erosive and/or has high sediment delivery.

The two cornbelt studies were based on the same general equilibrium LP model. This model included supply and demand relationships and quantified the distribution of control costs among regions, farmers, and consumers. Taylor and Frohberg (1977) evaluated economic effects of three rather restrictive environmental policies – insecticide and herbicide bans and reductions in fertilizer N applications to 55 or 110 kg/ha. The most significant conclusion was that such policies would in general benefit farmers but increase consumer costs. The same model was subsequently modified and used by Seitz et al., (1979) in additional studies of impacts of erosion control. The aggregate costs of such controls on farm income were small, but again, consumer food prices increased under certain restrictions.

The four studies listed in Table 4 illustrate the types of broad policy implications that can be generated by planning models. In general it would appear that the primary economic impacts of agricultural pollution control policies are associated with the distribution of costs and benefits among regions, producers, and consumers. Aggregate national or regional crop production and farm income do not appear to be greatly changed by most pollution control practices.

3.4 Watershed Planning Models

Nine applications of watershed planning models are summarized in Table 5. The policy implications of each study are limited to the specific watershed that was modeled and are not necessarily generalizable to other watersheds.

The first application (Alt et al., 1979) illustrates a standard approach to analysis of watershed pollution. The specific problem addressed was sedimentation of a downstream reservoir. An LP model of the watershed's cropland was used to evaluate erosion limits, constraints on sediment flux to the reservoir and subsidies for soil and water conservation practices. Reservoir sedimentation and soil and water conservation were also the subject of the work by Reneau and Taylor (1979), but their study included a much more complete accounting of social benefits and costs. Offsite sediment damage functions based on reservoir dredging and cleaning of flood control structures were included and the productivity benefits of soil conservation were estimated. Even so, it was determined that erosion control measures could not be economically justified in the watershed.

Onishi and Swanson (1974) also included offsite dredging costs in their model, but in this case it was optimal to reduce farmland erosion. Because the study also included nitrate leaching, the relationship between two environmental problems, groundwater pollution and reservoir sedimentation, could be investigated. As might be expected, sediment (erosion) controls did not also serve to control N pollution of groundwater.

The Casler and Jacobs (1975) model is similar to that of Alt et al. (1979), since P losses from a watershed in streamflow were all assumed to be associated with eroded soil. Hence erosion was the primary process modeled and P losses were obtained by multiplication by a constant. One of the general results of this study, which was also seen in most of the other applications, is that the marginal costs of nonpoint-source pollution control increase dramatically as higher levels of pollution reduction are sought.

The watershed modeling approach of Wineman et al., (1979), which is based on a study by Meta Systems, Inc., is unique. It establishes a modeling framework designed to describe the processes of agricultural nonpoint-source pollution from their origin in a farmer's field to their ultimate water quality impacts. At the present time, the approach is preliminary since although some testing has been done on the Black Creek watershed in Indiana, the general validity of the models has not yet been demonstrated.

The last four watershed applications involve models that are based on discrete simulations of pollutant transport. Unlike most other planning and management models, these four models incorporate detailed mathematical descriptions of the processes associated with nonpoint-source pollution. Model data needs are extensive, since many pollutant and economic parameters must be provided. The simulation models used in these studies are summarized in Table 2.

Williams and Hann (1978) have developed a decision theory methodology for evaluating strategies for controlling agricultural nonpoint sources. An LP model is designed that maximizes a weighted sum of decision-makers' utilities subject to water quality constraints. Coefficients for chemical and sediment losses are provided from the simulation model. The approach appears to be computationally feasible, but no attempt was made to actually estimate utilities. Tseng's (1979) model also involves a two-step modeling approach, but in this case simulation is used as a means of evaluating the environmental effects of land use plans produced by an optimization (LP) model.

In the two salinity models (Scherer, 1977; Bardaie, 1979), the simulation models described in Table 2 are integral parts of an optimization model. In Bardaie's model, this integration produces a model that is difficult to solve, and simplifications were necessary to obtain solutions by either DP or separable LP.

3.5 Farm Management Models

The final group of models presented in this section are extensions of the standard LP farm planning and budgeting models that have been used for many years. The addition of environmental parameters to such models has been a logical means of exploring the effects of agricultural pollution control on farm management. Unlike regional and watershed models, farm models are microscale, and provide estimates of the impacts of environmental policies on the farmer's day-to-day activities. In general, the models should provide more sensitive indicators of the impacts of policies than the larger scale models are capable of.

Each of the six models listed in Table 6 provides estimates of cropland erosion using the USLE. Only one model (Smith et al., 1979) combines erosion with sediment delivery ratios to determine the losses of eroded soils to surface waterways. Thus, Smith et al. were able to compare erosion and sediment control programs. They concluded that uniform imposition of erosion controls on all of a farmer's fields is not an efficient way to control stream sediment losses. This result is significant since it suggests that policies to control sediment are not equivalent to, and may be incompatible with, other policies to reduce erosion.

White and Partenheimer (1979) modeled 12 Pennsylvania dairy farms to evaluate the effects of adopting soil conservation plans recommended by the US Soil Conservation

TABLE 5 Applications of nonpoint-source planning models to watershed water quality management.

Reference	Environmental emphasis	Location	Optimization procedure	Method of pollution estimation	Policy implications
Alt et al. (1979)	Sediment	Iowa River-Coralville Reservoir, Iowa (3,800 km^2)	LP	USLE, delivery ratios	Large (75%) reductions in sediment flux possible with small (4%) increase in farm costs. Greater reductions increase costs sharply.
Reneau and Taylor (1979)	Sediment	Lavon Reservoir, Texas (1,930 km^2)	Enumeration	USLE delivery ratios, entrapment in flood control structures	Total costs (farm income losses plus government subsidies) of erosion control plans exceed benefits from abatement of offsite sediment damages.
Onishi and Swanson (1974)	1. Sediment 2. N in percolation	Forest Glen, Illinois (5 km^2)	LP	USLE, delivery ratios for sediment, functional transport model for N	1. Assessment of farmers for offsite sediment damages reduces farm sediment losses 2. Sediment restrictions do not also control N losses. 3. Reduction of N in percolation to 10 mg/1 severely reduces farm income.
Casler and Jacobs (1975)	P in runoff	Fall Creek, New York (330 km^2)	LP	Functional transport model based on USLE	1. Without conservation practices, reduction of P losses greater than 10–20% substantially decreases farm income. 2. With conservation practices, increased feed purchases, P losses reduced 30–40% at small cost.

Wineman et al. (1979)	Water quality (subjective evaluation)	Black Creek, Indiana	None	Functional transport models	Nonpoint-source controls have non-uniform impacts on water quality; water quality/economic tradeoffs of policies differ among water quality problems.
Williams and Hann (1978)	1. Sediment 2. N, P in runoff	Little Elm Creek, Texas (101 km^2)	LP	Discrete simulation transport model	The study demonstrated that a decision theory framework for evaluating non-point-source pollution controls is in principle feasible.
Tseng (1979)	N in streamflow	Fall Creek, New York (330 km^2)	LP	Discrete simulation transport model	Watershed land use plans based on re-commended conservation practices reduced N export in streamflow.
Scherer (1977)	River salinity	Hypothetical 4 district example	DP	Discrete simulation transport model	Reallocation of water rights among water users by a market mechanism can increase total returns from irriga-tion water use.
Bardaie (1979)	River salinity	Imperial Valley, California	DP, LP	Discrete simulation model	Long-term management of salinity problems is possible with a dynamic program of changing diversions and crop selections from year to year.

TABLE 6 Application of farm management models.

Reference	Environmental emphasis	Location	Optimization procedure	Method of pollution estimation	Policy implication
Smith et al. (1979)	Sediment	New York, Iowa, Texas	LP	USLE, delivery ratios	1. Sediment losses from farms can often be economically controlled by concentrating control practices on field with high sediment delivery. 2. Erosion and sediment control plans are often substantially different.
White and Partenheimer (1979)	Erosion	Pennsylvania	LP	USLE	Conservation plans developed by US Soil Conservation Service usually decrease farm income (even with cost-sharing). These plans often require less profitable rotations.
Miller and Gill (1976)	Erosion	Indiana	LP	USLE	Uniform erosion controls will have differential effects on farm income. Small farms and farms with erosive soils will be most adversely affected.
McGrann and Meyer (1979)	1. Erosion 2. Pesticide use 3. Fertilizer applications	Iowa	LP	USLE	1. When erosion control requires rotation changes, costs can be substantial. 2. Income effects of erosion controls depend on soil resources. 3. Cost-sharing programs for structural measures are often inefficient. 4. Fertilizer reductions have more adverse impacts than pesticide bans.
Coote et al. (1975, 1976)	1. Erosion 2. Nutrients in runoff	New York	LP	Functional transport models	The effects of waste management regulations on a farmer are primarily determined by soil resources.
Haith and Atkinson (1977)	1. Erosion 2. Nutrients in runoff	New York	LP	Functional transport models	Greater farming intensity as indicated by number of cows/ha increases erosion and nutrient losses primarly due to more intensive cropping practices.

Service. These plans were compared with unrestricted plans for profit maximization and plans based on soil loss constraints. Both of the latter plans provided more flexibility to the farmer and in most cases generated more income than conservation plans. As was also seen by Smith et al. environmental controls exert their most adverse effects on income when they force changes in crop rotations.

Results from the modeling of four farms in Indiana (Miller and Gill, 1976) demonstrate the distributional effects of pollution control policies seen in the regional planning applications. Farm size and soil resources influence the impacts of control programs on the farmer. The work on McGrann and Meyer (1979) confirmed these observations, and indicated that government cost-sharing programs often do not encourage efficient (cost-effective) erosion control programs. A similar conclusion was reached by Smith et al.

The final two models in the table provide more complete descriptions of farm pollutant losses since they include estimates of nutrient losses in runoff. The estimates are determined by functional transport models based on the ULSE or US Soil Conservation Service runoff equation. The work of Coote et al. (1975, 1976) was designed to evaluate the effects of proposed manure management regulations on income and soil nutrient losses from dairy farms. It was found that the regulations did not necessarily reduce pollutant losses but could, depending on a farm's soil resources, decrease farm income. The model developed by Haith and Atkinson (1977) was a simpler version of the Coote et al. model and was used to investigate the effects of dairy farming intensity, measured in cows/ha on soil and nutrient losses. Although losses increased with intensity, the effect was caused more by cropping changes than the disposal of additional quantities of manure.

4 CONCLUSIONS

Two principal groups of mathematical models are available to aid in the analysis of agricultural nonpoint-source pollution. Chemical transport models estimate chemical losses from croplands to water bodies. Planning and management models are used to evaluate tradeoffs between environmental and agricultural production (economic) objectives. The development and application of these models have been rapid and haphazard. This paper is both a review of the current status of modeling activities and an attempt to establish a coherent framework, or classification based on model attributes, that can be used to compare and evaluate alternative modeling approaches.

Three types of chemical transport models are apparent. Continuous simulation models describe basic chemical transport processes with differential equations that are subsequently solved by analytical or numerical techniques or specialized computer languages. These models are generally applied to estimation of chemical losses in percolation or groundwater. Most continuous simulation models must be calibrated and are difficult to solve for realistic field conditions. At present, the modeling approach is perhaps best described as theoretical.

Discrete simulation models comprise the second, most common, type of chemical transport models, and describe transport processes with sequential algebraic equations based on water and chemical mass balances. Several of these models are operational tools for water quality planning since they are computationally efficient, do not require extensive data, and have been tested in field or watershed applications. However, none of the models has been tested extensively, and a great deal of further work is necessary before discrete simulation models of chemical transport can be routinely applied to agricultural pollution problems.

The final group of chemical transport models consists of functional models that do not attempt to simulate transport processes. Rather, the models are simple empirical or intuitive equations that predict chemical losses based on minimal data requirements. It is not surprising that these models have been widely used since they do not require extensive resource commitments. However, the accuracy of functional models is largely unknown, and they may not be reliable means of evaluating nonpoint-source controls.

Planning and management models are in principle the most useful models for policy-making since they provide estimates of economic and water pollution impacts of management practices. All such models are based on budgeting approaches which are usually solved by linear programming. Modeling applications are classified within three groups. Regional impact models are used for macroscale studies of farm and consumer income. Applications of such models in the USA have suggested that environmental controls on agriculture will have little impact on national or cornbelt income, but will increase prices to consumers and change regional crop distributions. Watershed planning models are applied to specific water quality problems and evaluate impacts of management practices, subsidies, and taxes on pollution and farm income. Farm management models evaluate the impacts of pollution control on the activities of individual farmers. Applications of these models have indicated that economic impacts will differ markedly from farm to farm.

Planning and management models have provided useful policy-making information. However, the economic components of the models are much better developed than components for prediction of pollution. The majority of models are based on the Universal Soil Loss Equation (USLE), and water quality impacts are limited to sedimentation estimates by empirical delivery and transport relationships. This is due largely to the limited availability of tested chemical transport models, and it can be anticipated that as these models become more reliable and generally accepted, more refined pollution estimates will be incorporated into planning and management models.

If the control of agricultural nonpoint-source pollution remains an important element of environmental planning, it is clear that much remains to be done in the development and testing of mathematical models. Models provide the quantitative information required for rational policy-making and in many, if not most situations, models will be the only feasible means of generating this information. In a relatively short time, scientists, engineers, and economists have produced a substantial body of work which will provide the basis for sustained future efforts. It is important for researchers, practitioners, and policy-makers to realize, however, that only a modest beginning has been made. The control of point-source discharges of wastewaters is based on more than a hundred years of research and testing, and a continued investment in nonpoint-source models will be necessary to establish a comparable level of technology.

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ABSTRACTS OF OTHER IIASA PUBLICATIONS

Runca, E., A. Longhetto, and G. Bonino, Validation and Physical Parametrization of a Gaussian Climatological Model Applied to a Complex Site. IIASA Research Report RR-82-1, January 1982.
Reprinted from *Atmospheric Environment*, Vol. 16(2), 1982, pp. 259–266.

Seasonal SO_2 average concentrations have been simulated in a topographically complex-coastal site, by means of a Gaussian-type model. The model diffusion equation has been parametrized on the basis of the results from a series of field experiments conducted in the area to characterize the dynamic and thermodynamic properties of the local atmosphere. The validity of the adopted model formulation and physical parametrization has been discussed by comparing simulated and measured concentration values separately for unstable, neutral, and stable situations, and by testing the model sensitivity with respect to changes in the parameters used. The analysis has shown that definition of the model physical parameters as indicated by the field experiments leads to a very satisfactory agreement between the calculated and measured concentrations. Therefore the model can be considered a suitable tool to implement air quality strategies in the area on a climatological basis. The study has been applied to the complex coastal site of La Spezia, Italy, for the period March 1975–February 1977.

Keyfitz, N., and D. Philipov, Migration and Natural Increase in the Growth of Cities. IIASA Research Report RR-82-2, January 1982.
Reprinted from *Geographical Analysis*, Vol. 13(4), 1981, pp. 287–299.

Roughly 1.8 billion people, 42 percent of the world's population, live in urban areas today. At the beginning of the last century, the urban population totaled only 25 million. According to recent United Nations estimates, about 3.1 billion people, twice today's urban population, will be living in urban areas by the year 2000.

Scholars and policy makers often disagree when it comes to evaluating the desirability of current rapid rates of urban growth and urbanization in many parts of the world. Some see this trend as fostering national processes of socioeconomic development, particularly in the poorer and rapidly urbanizing countries of the Third World, whereas others believe the consequences to be largely undesirable and argue that such urban growth should be slowed down.

Migration and natural increase are the two contributors to urban population growth. The complex question of which of the two is more important is analyzed in this article through the use of simulation techniques. Immediate effects are contrasted with long-run effects, and the age of the migrant is considered as an important factor, along with the crucial variable of rural population growth.

Umnov, A., and M. Albegov, An Approach to Distributed Modeling. IIASA Research Report RR-82-3, February 1982.
Reprinted from *Behavioral Science*, Vol. 26, 1982, pp. 354–365.

The problem of computer linkage of different mathematical models into a whole system in order to investigate their joint behavior with more common criteria and constraints seems to receive more and more consideration. Many works on analyzing the behavior of complex systems are based on building large-scale integrated models and sequentials using decomposition and aggregation procedures. In this article an approach is described that permits the investigation of a set of linked subsystems without explicitly building any integrated model.

This article represents a description of a particular approach that might be referred to as "distributed modeling." It deals with conceptual systems in general, which might be used to model concrete systems at any level. The use of the method is illustrated by the practical application of the development of a system of regional models. This approach, based on the smooth version of the sequential unconstrained minimization techniques (SUMT), can be considered from a mathematical point of view as a realization of the general decomposition scene.

Ledent, J., Two Essays on Alonso's Theory of Movement. IIASA Research Report RR-82-4, February 1982.
Reprinted from: (1) *Sistemi Urbani*, Vol. 2/3, 1980, pp. 327–358; (2) *Environment and Planning A*, Vol. 13, 1981, pp. 217–224.

(1) First, it is shown that Alonso's general theory of movement relies on a standard doubly constrained spatial interaction model. Such a finding then suggests the use of a biproportional adjustment method (RAS method) to estimate adequately the systemic variables specified in the underlying model. This eventually leads to the development of a complete and precise methodology for calibrating the Alonso model. This methodology is illustrated with the help of an application to data on interprovincial migration in Canada.

(2) This paper compares the system of equations underlying Alonso's theory of movement with that of Wilson's standard family of spatial-interaction models. It is shown that the Alonso model is equivalent to one of Wilson's four standard models depending on the assumption at the outset about which of the total outflows and/or inflows are known. This result turns out to supersede earlier findings – inconsistent only in appearance – which were derived independently by Wilson and Ledent. In addition to this, an original contribution of this paper – obtained as a by-product of the process leading to the aforementioned result – is to provide an exact methodology permitting one to solve the Alonso model for each possible choice of the input data.

Nanjo, Z., T. Kawashima, and T. Kuroda, Migration and Settlement: 13. Japan. IIASA Research Report RR-82-5, February 1982.

In this report, authors from three Japanese institutions discuss changing migration patterns in their country. Emphasizing the current population shifts away from metropolitan areas, they analyze recent demographic dynamics in Japan, first with a 15-region and then an 8-region disaggregation of national population data. The report ends with a brief survey of major population policies that have been adopted in the last 30 years.

Aspden, P., L. Mayhew, and M. Rusnak, DRAM: A Model of Health Care Resource Allocation in Czechoslovakia. IIASA Research Report RR-82-6, February 1982.
Reprinted from *Omega: The International Journal of Management Science*, Vol. 9(5), 1981, pp. 509–518.

This paper presents an application to data from Czechoslovakia of a health care resource allocation model called DRAM (Disaggregated Resource Allocation Model). DRAM was developed by the health care systems modeling group at the International Institute for Applied Systems Analysis (IIASA). It attempts to predict the consequences of resource-level changes, in terms of the numbers of patients treated in each clinical category and the quality of care they receive in each mode of treatment. In this application, seven acute clinical categories and two types of resources (hospital doctors and hospital beds) are selected for examination in one mode of treatment – in-patient care. Some parallels are drawn with a comparable application in the UK.

Beck, M.B., Operational Estimation and Prediction of Nitrification Dynamics in the Activated Sludge Process. IIASA Research Report RR-82-7, March 1982.
Reprinted from *Water Research*, Vol. 15, 1981, pp. 1313–1330.

This paper examines the feasibility and discusses the potential of applications of on-line real-time state estimation and prediction in operational control of the activated sludge process. In particular, the dynamics of nitrification are considered with reference to the activated sludge unit at the Norwich Sewage Works in eastern England. A recursive estimation algorithm, the extended Kalman filter, is applied both for reconstructing operating information on the variations in nitrifying bacterial population concentrations and for making predictions of process performance under assumed scenarios for the short-term future operating conditions of the plant. Time-series field data from the Norwich Works are used for the former analysis. Considerations of uncertainty and the possibility of rapid major perturbations in performance, for example, due to spillages of toxic substances or the loss of solids over the clarifier weir, are of special importance to the discussion. The paper is introduced and concluded with some more general comments on the roles of operator experience and decision-making and man–machine interaction in wastewater treatment plant control.

Beck, M.B., Systems Engineering and Microelectronics in Water Quality Management. IIASA Research Report RR-82-8, March 1982.
Reprinted from F. Fallside, editor, Microelectronics in the Water Industry, a supplement to the *Journal of the Institution of Water Engineers and Scientists*, November 1981, pp. 5–15.

This paper is based largely upon the results of a recently completed policy study on the feasibility of operational water quality management. The purpose of the study was both to make the assumption that operational management is "necessary and desirable" more convincing and to bring together an analysis of those perspectives (economics, technological innovation, risk/reliability, and institutional arrangements) that influence the desirability of operational management. Management of water quality, however, is clearly not merely a matter of wastewater treatment. Nor is the feasibility of operational management determined solely by advances in automation, computers, and instrumentation, although electronic engineering innovations in the water and wastewater industries have themselves made operational management, to some considerable extent, both possible and popular. It is therefore important to examine the kind of background "problems" in water quality management that will undoubtedly shape the need for further such applications. Accordingly, it is equally important to discuss the potential of what might be possible for the application of microelectronics in water quality management. These topics are examined in this paper.

Runca, E., A Practical Numerical Algorithm to Compute Steady-State Ground Level Concentration by a K-Model. IIASA Research Report RR-82-9, March 1982.
Reprinted from *Atmospheric Environment*, Vol. 16, 1982, pp. 753–759.

A numerical algorithm to compute steady-state ground level concentration from elevated sources by means of a K-model that takes into account the spatial variability of wind and diffusivity and neglects horizontal diffusion is discussed. The boundary value problem to be treated, also for a point source, is always reduced to a two dimensional one and is solved on an optimized grid. In this way the proposed method is made computationally comparable with the classical Gaussian plume model.

Maurer, H.A., W. Rauch, and I. Sebestyen, Videotex Message Service Systems. IIASA Research Report RR-82-10, March 1982.
Reprinted from *Electronic Publishing Review*, Vol. 1(4), 1981, pp. 267–296.

Electronic message services supported by interactive videotex-like systems are described, classified, and analyzed in terms of the specific characteristics of such systems. A comparison of videotex message systems with other similar media is undertaken and the introduction of such a service on an experimental basis is suggested. Recommendations are made to integrate special features, such as gateway services and an integrated Electronic Directory System, into such systems.

Maurer, H.A., W. Rauch, and I. Sebestyen, Alphabetic Searching in Videotex Systems. IIASA Research Report RR-82-11, March 1982.
Reprinted from *Electronic Publishing Review*, Vol. 1(3), 1981, pp. 217–223.

Of the four major types of interactive videotex systems currently being tested (Telidon, Télétel, Captains and Prestel-like), only one (Télétel) permits the use of alphabetic key words for searching. It is claimed that alphabetic keyword searching should be incorporated into future videotex systems. Methods of alphabetic keyword searching in the absence of alphanumeric keyboards are then discussed. A novel technique is proposed, which has been implemented recently on Prestel-like systems as an interim solution whenever genuine alphabetic searching is not available.

Sebestyen, I., Computerized Message Sending and Teleconferencing in an International Environment: Present and Future. IIASA Research Report RR-82-12, March 1982. Reprinted from *Electronic Publishing Review*, Vol. 1(3), 1981, pp. 193–204.

Computerized message sending and teleconferencing techniques are presently widely used in an international environment. The paper describes the present status (experience, problems, solutions) of electronic message exchange activities at an international research organization, the International Institute for Applied Systems Analysis (IIASA), and gives a short outline of some of the future prospects in this field.

BIOGRAPHIES

Csaba Csáki, Hungary

Csaba Csáki joined IIASA in September 1976. His work at IIASA focuses on the modeling of the world's food and agriculture problems, and the development of national food and agriculture policy models of European CMEA and other countries. Dr. Csáki received his university degree (1963) and doctorate (1964) in Agricultural Economics from the Karl Marx University of Economics in Budapest. He became a Candidate of Economic Sciences of the Hungarian Academy of Sciences in 1971. Since 1963 he has been with the Department of Agricultural Economics at the Karl Marx University, where he leads a group dealing with the teaching of quantitative methods in agriculture and farm management economics. Dr. Csáki's scientific interests include: agricultural economics; farm management economics; modeling of agriculture; and planning, analysis, and simulation in agriculture. He is a member of the Hungarian Economic Society, the European Association of Agricultural Economists, and the Committee for Agricultural Planning and Management of the Hungarian Academy of Sciences.

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Douglas A. Haith is a member of the faculty in the Departments of Agricultural Engineering and Environmental Engineering at Cornell University. He received his Ph.D. from Cornell in civil engineering in 1971 and became an Assistant Professor there the same year. Dr. Haith has also worked with the engineering firm of Quirk, Lawler, and Matusky in 1967–68 as Project Engineer for reservoir simulation and water supply studies, and again in 1973–74 as Project Manager and Senior Engineer for regional water quality planning. From 1966 to 1967, he was a hydraulic engineer for Charles A. Maguire and Associates in Boston. He is the author of *Environmental Systems Optimization* (Wiley, 1982) and co-author of *Water Resource Systems Planning and Analysis* (Prentice-Hall, 1982). In 1981 Dr. Haith was awarded the Walter L. Huber Civil Engineering Research Prize of the American Society of Civil Engineers.

F. Desmond McCarthy, USA

Desmond McCarthy joined IIASA's Food and Agriculture Program in September 1979 to work on the Brazilian and Egyptian models. He is also doing methodological work in the field of economics. Dr. McCarthy is from the United Nations Food and Agriculture Organization. Dr. McCarthy received his M.E.E. in 1963 and his Ph.D. in Electrical Engineering in 1966, both from New York University. He also holds an M.Sc. in Economics from the Massachusetts Institute of Technology. As a member of an analysis group of MIT's Draper Laboratory (1966–1969) he was involved in statistical analysis, sampling, and development of software systems for data analysis. From 1969 to 1975 he was Associate Professor at Northwestern University, teaching courses on systems theory. From 1974 to 1978 Dr. McCarthy was with the Center for International Studies at MIT where he was involved with work on Egypt, Pakistan, and Brazil. Since 1978 he has been Food and Nutrition Advisor to the Government of Kenya. Dr. McCarthy is a member of the American Economic and American Agricultural Associations as well as other professional societies. He is the author of a substantial number of publications on food, nutrition and economic planning.

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