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SYSTEMS RESEARCH INSTITUTE
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INTEGRATED RURAL/SPATIAL DEVELOPMENT: ELEMENTS OF SYSTEMS ANALYTIC APPROACH

Edited by

Andrzej Straszak and Jan W. Owsinski

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Integrated Rural/Spatial Development: Elements of Systems Analytic Approach, edited by Andrzej Straszak and Jan W. Owsinski

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III. PRODUCTION PLANNING AND POLICY DESIGN

AN INTRODUCTION

Jan W. Owsiński

It is assumed throughout this volume that agricultural activities dominate economically and/or socially in rural systems, even though a large portion of rural population may depend on some other source of income. Hence, in designing an outline for integrated rural development, agricultural activities should form a core of both the development design procedure and of the resulting outline itself. Agriculture provides income and food, and requires inputs, including local resources. Thus, this set of activities constitutes a link between the resource system, at which we have looked before, and the social system, whose some aspects shall be undertaken in a later chapter.

The very notion of development refers to passing of time, and in particular, it refers to future. Hence, it is necessary to derive projections or plans from the present state of affairs, expectations of those who shape the development course and available resources. It should be assumed that increasing complexity of interrelations within the system, which limits severely the capability of individual actors to decide rationally, as well as growing gap between expectations and actual achievements, especially in the attained level of life, make it necessary to perform planning. Planning presupposes intelligent intervention into the processes taking place within the system, i.e. the capability of carrying out effectively such intervention, and the analytical and design capacities beyond the scope of individual actors, subject to intervention planned.

Thus, the planning method envisaged should have the following features:

- appropriate functioning as a mere forecasting tool, i.e. under the business-as-usual assumption, ensuring that conclusions drawn are correct at least in this case,
- consideration of goals and expectations of the main groups of actors shaping the processes within the system,
- consideration of the effectiveness of intervention measures, meant to bring about the desired course of affairs,
- possibility of sensitivity analysis of planning results with regard to main quantitative assumptions about e.g. resource volumes, i.e. determination of changes in results which can be brought about by shifts in system's conditions.

Since one is primarily interested in plans which are in some sense best /"optimal"/ it is important that the planning method ensure:

- generation of alternative plans and
- choice of best variants according to
- explicit quantitative criterion which serves as a measure for choosing the best plan alternative.

All these assumptions sum up to a procedure shown in Fig. 1 below.

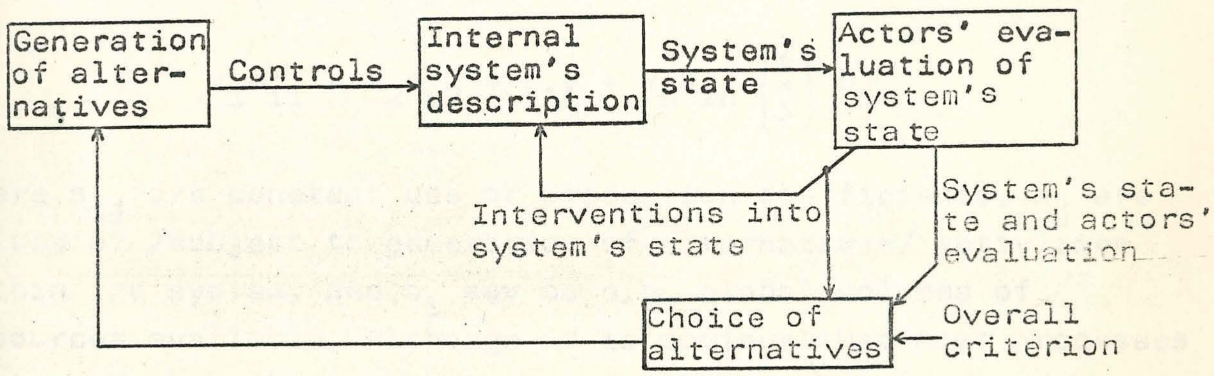

Fig. 1. Elements entering the planning and policy design procedure and their interrelations.

Within the above figure its important elements, such as system's description, actors' goals and objectives, and possibilities of intervention make up a model of the system, used as a planning and policy design tool.

The procedure outlined stresses the aspect of choice. It may, of course, happen that there is little room for choice, but then, the very function of planning looses its sense.

It is usually not very difficult to put down all the individual relations which are kept to in the system /e.g. product balances, monetary balances, or resource limitations/ in a rigorous mathematical way, at least through rough approximations. It may be more difficult to formulate goals of actors participating in rural development process. However, the most difficult task is to consider all those conjointly, to say nothing of generation and review of alternatives. Hence, it has become necessary to apply computer-based methods for that purpose.

These computer-based methods allow to generate and review alternatives in a reasonable time, and to choose best alternatives. They also provide some additional information, related to value of resources, satisfaction of actors etc. The most often used method is based upon the linear programming /LP/ techniques. LP assumes that balances entering the internal description of the system are all linear, as well as objective functions of all actors, including the main criterion, i.e. they can be expressed in the form

$$x_1 a_{i1} + x_2 a_{i2} + \dots + x_n a_{in} \left\{ \begin{matrix} \leq \\ = \\ \geq \end{matrix} \right\} b_i$$

where a_{ij} are constant use or production coefficients, x_j are values of /subject to generation of alternatives/ activities within the system, and b_i may be e.g. global volumes of resources available. Although it is obvious that most processes taking place within the rural system are nonlinear, there is very little evidence as to their precise characteristics, which would justify their definite shape, and moreover, it is obvious that locally, when activity and parameter values do not vary too much, linear assumptions hold with adequate accuracy. Thus, application of LP techniques is fully justified, provided care is taken of potential important divergences in comparison with initial conditions of parameter definition.

Various approaches based upon the philosophy outlined will be presented in this chapter. The papers show how relations describing the system and its conditioning enter the LP models and how the results obtained should be interpreted in planning and policy design practice.

Since all the papers presuppose the use of computing equipment it should be tested, for each application envisaged, what parameters of such equipment are needed in order to appropriately apply any of the LP modelling formulations here described.

Software to be used with almost any computing equipment can include LP codes prepared for solving optimization problems formulated as LP. The problem of technical nature arises, namely that of preparation of the system's description and other procedure elements in the language assumed by that particular LP code.

Thus, taking into account computer implementation, the technical procedure takes on the form shown roughly in Fig. 2.

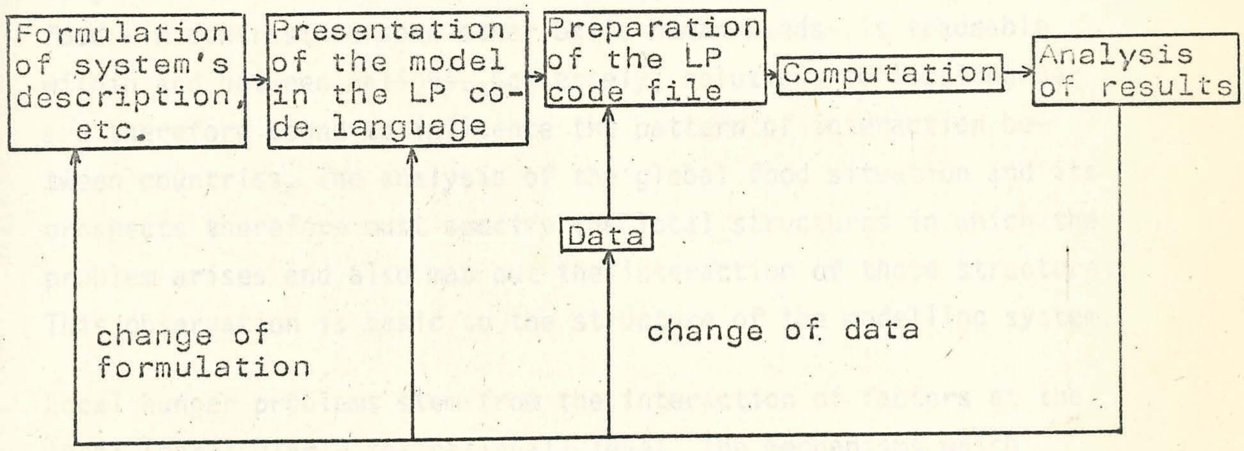

Fig. 2. Outline of computer-oriented procedure

MODELLING AGRICULTURAL SYSTEMS WITHIN THE FRAMEWORK OF NATIONAL MODELS

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Abstract

In this paper a price endogenous model for Thailand will be discussed. Emphasis of the model is on food production and distribution. Logically the model can be divided into an agronomic and an economic part. In the agronomic part technical production relations are generated which are used as input in the economic part. The economic part includes a supply component and an exchange component. The supply production behaviour is described by means of a set of recursive linear programmes. In the exchange component income and price formation takes place. The model distinguishes 19 commodities, 5 regions and 28 income groups.

1. Introduction

Hunger is in the first place a local phenomenon, determined by a variety of factors amongst which physical, economic, social and demographic ones are predominant. But the extent and degree of hunger can be influenced by interactions between countries as food -in contrast to some other basic human needs- is tradeable within and between nations. Conversely, solutions to local hunger are therefore bound to influence the pattern of interaction between countries. The analysis of the global food situation and its prospects therefore must specify the local structures in which the problem arises and also map out the interaction of those structures. This observation is basic to the structure of the modelling system.

Local hunger problems stem from the interaction of factors at the local (particularly the national) level. The mechanisms which generate these local situations and determine their behaviour over time must therefore be identified. Therefore, the objective is to develop a set of models presenting national agricultural systems which are embedded in national economies interacting with each other.

Country models have a key role in the system, recognizing the national control over resources and their uses and the role of national government policies. The interaction between countries is recognized as complex, as local and global changes mutually condition each other.
The Centre for World Food Studies takes part in a worldwide effort to build a modelling system which can analyse these various dimensions of the food problem and their interactions. A number of other institutions also engage in the national modelling part of the work. The International Institute of Applied Systems Analysis (IIASA) in Vienna provides the umbrella for these research efforts which intend to explore national and international food policy options. The Food and Agriculture Program (FAP) of IIASA started in 1976 under the leadership of Ferenc Rabar of Hungary.

FAP-SOW model approach

A central task of the FAP program is to study the impact of national policies of both developed and developing nations on hunger and malnutrition in the world and to evaluate the consequences of new international agreements in the field of food and agriculture.
The research strategy is to develop a simulation model containing about 25 national models which interact through trade and capital flows. The model operates with a one year time increment and has a time horizon of 15-20 years. Country experts independently develop national models which should be linkable into one global model. The models should therefore satisfy basic linkage requirements.

- International trade variables should follow a common commodity classification (i.c. 18 agricultural and 1 residual, non-agricultural commodity).
- Imports and exports of commodities should be generated on a yearly basis.
- Imports and exports should be functions of world market prices, which are insensitive to the absolute level of prices.

Figure 1

ACTORS IN THE INTERNATIONAL MODEL

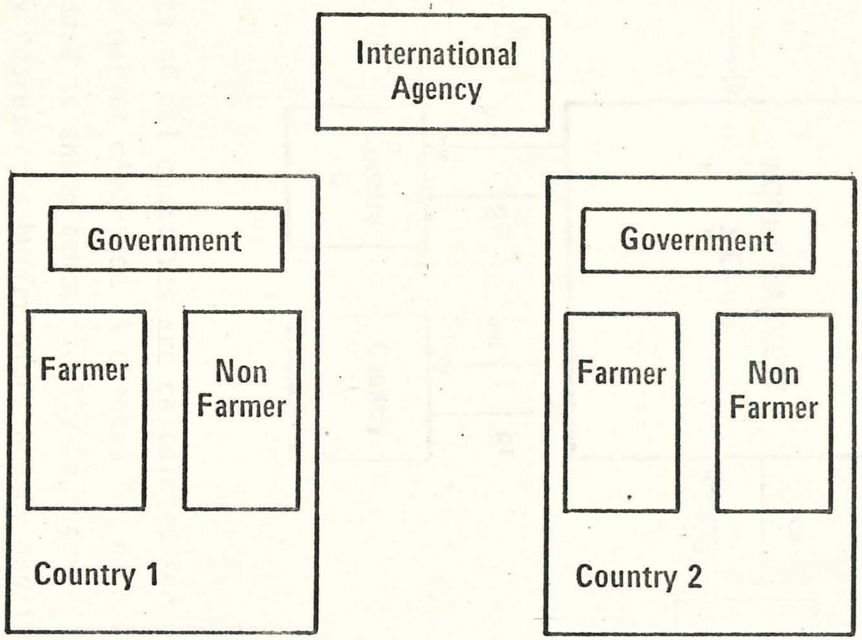
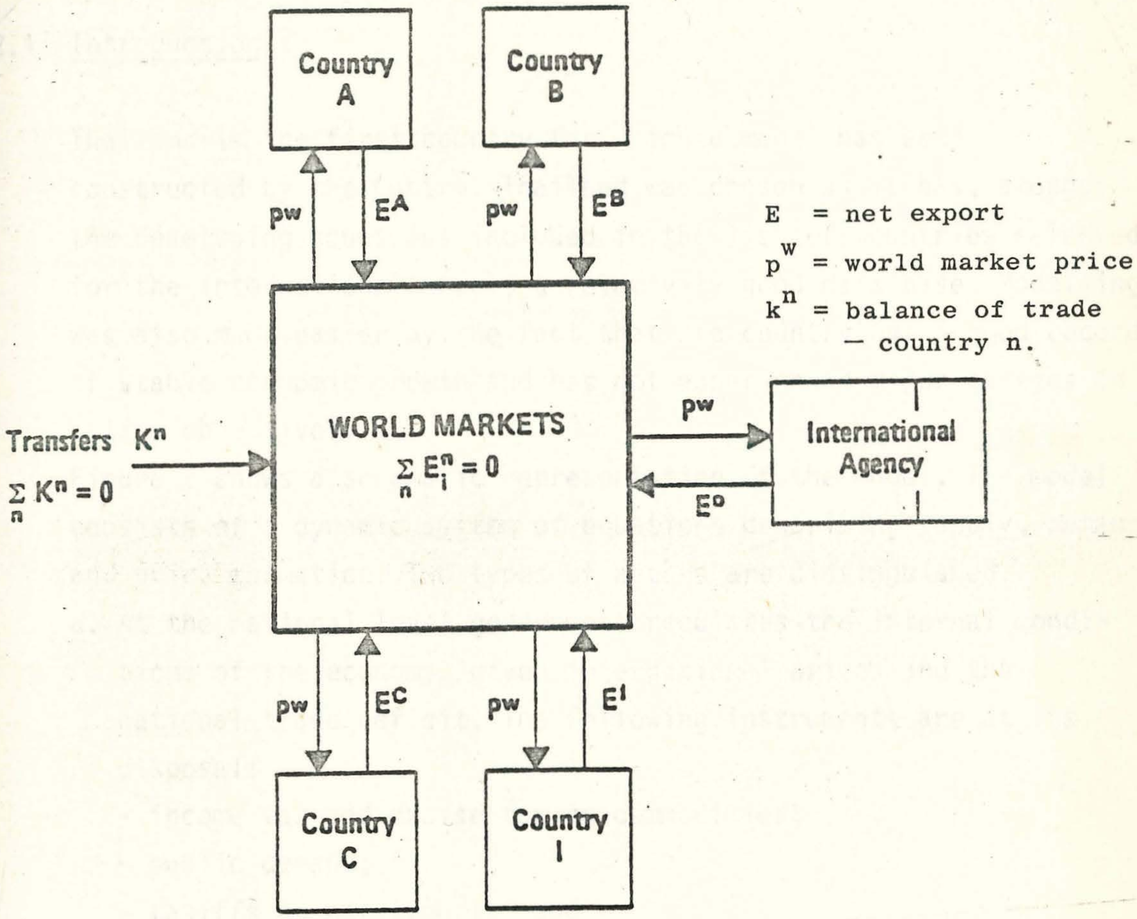


Figure 1a

INTERNATIONAL LINKAGE



Net exports of all countries are calculated for a given set of world prices and market clearance is checked for each commodity every year. The procedure is shown schematically in figure 1. The international agency may represent a buffer stock agency and its policies can be evaluated within a framework in which countries react to the agency. Required algorithms and computational technics of this system have been developed by M. Keyzer.

2. An Application: Thailand

2.1 Introduction

Thailand is the first country for which a model has been constructed by the Centre. Thailand was chosen as it has, amongst the developing countries included in the list of countries selected for the international model, a relatively good data base. Modelling was also made easier by the fact that the country has a good record of stable economic growth and has not experienced major changes in policy objectives.

Figure 2 shows a schematic representation of the model. The model consists of a dynamic system of equations describing supply, demand and price formation. Two types of actors are distinguished.

a. At the national level government regulates the internal conditions of the economy, given international prices and the national trade deficit. The following instruments are at its disposal:
   - income tax and excise tax on commodities;
   - public demand;
   - tariffs on net import; and
   - quotas on net import.

b. Within each region, income groups (farmers and non-farmers) supply and demand goods at ruling prices.

The model can be divided into two main components: the exchange component and the supply component. In this order these will be discussed below.

2.2 The Exchange Component

This part of the model consists essentially of a system of simultaneous equations which is solved to derive the equilibrium price for the 19 IIASA-commodities. The equilibrium price is the price that clears all commodity markets after allowing for international trade, and taking fully into account the restrictions imposed by government policies. In equilibrium, each economic agent satisfies his budget constraint.

In order to describe demand behaviour, for each of the 28 income-groups distinguished in the model complete demand systems have been estimated. For each incomegroup a savings function is also included. Available savings determine investments. A share equation allocates available investment funds between the public and private sectors and between agriculture and non-agriculture.

The income received by each income-group consists of:

a. value of net supply at producers prices,
b. net receipts for factor services (interest, wage, rent),
c. income transferred from abroad,
d. income transferred from other income groups.

Special consideration is given to the modelling of government policies. No distinction is made between target and instrument variables. Policy variables are defined as variables in which the government is interested and for which it has defined a target value and a set of bounds. Policy targets will, as a rule, be incompatible with each other. These incompatibilities are resolved in the model by specifying adjustment rules. These adjustment rules postulate a hierarchy in government preferences. Formulation of government policies in this way has the advantages that

- the priorities and targets can be discussed with policy makers;
- the model has a solution even in the presence of conflicting targets;
- inequalities can be introduced in an easy way.

The exchange component takes supply of agricultural and non-agricultural commodities as given. This is reflected in a fixed endowment for each income group. Agricultural supply is determined in a detailed linear programming model. Non-agricultural production is determined by labour and capital using a production function with a constant elasticity of substitution. Labour supply is determined by an employment function. Capital supply depends on past investment and an exogenous depreciation rate. Full utilization of productive capacity is assumed.

When the equilibrium price is determined, the agents can carry out their expenditure plans and another round of supply and exchange can start.

As a first approximation for Thailand it is assumed that all producers and all consumers face the same price. Available statistical evidence shows that regional price disparities are fairly small in Thailand. For the timebeing, the same processing level will be assumed for all income groups. This assumption is not realistic and will have to be modified in due course.

From one period to the next, several adjustments take place:

a. Population growth takes place at an exogenously specified rate,
b. Migration decisions are carried out; permanent migration depends on the income differential between the rural area and Bangkok,
c. Investment is added to the capital stock.

2.3 The Agricultural Production Module

The farm sector in Thailand is a highly decentralized decision-making system made up of about 4 million fairly independent farmers. Given the nature of his environment which consists of all other farms, the markets for inputs and outputs, physical conditions, infrastructure, government policies, all kind of institutions, etc., the individual farmer tries on the basis of limited information, to reach his goals. This basic characteristic of the Thai agricultural sector is the starting point for the formulation of the supply module. For the individual farm the possible (inter-) actions and the environmental constraints have been described. Obviously, it is impossible to describe the state of affairs for all farms. Therefore the behaviour of representative farms has been modelled. These models have been used as the basis for describing the behaviour of the sector as a whole. Similarities in farming structure, i.e. in farm size, topography, climate, etc., were the selection criteria in determining the representative farms.

In Thailand we can distinguish six more or less homogeneous agricultural regions (figure 3):

(1) Northeast,
(2) Upper north,
(3) Lower north,
(4) Central plain,
(5) Eastern/western parts of the Central region, and
(6) South.

Within each region three farm sizes were distinguished:

small farms (0 - 10 rai)
medium farms (10 - 30 rai), and
large farms (> 30 rai).

In this way 18 representative farms (6 regions x 3 farm sizes) were modelled. In modelling a representative farm, emphasis has been given to the main factors only, which influence the decisions regarding the farm and non-farm production processes.
For the average Thai farmer these main factors are:

1. The competition among different outputs for the same inputs (cf. land, labour, etc.);
2. The integration of animal and crop production;
3. The possibility of performing production activities with different input combinations (technologies);
4. The integration of the household and the farm;
5. The possibilities of earning an income outside agriculture;
6. The attitude towards risk and uncertainty;
7. The influence of the government;
8. The interactions with the physical environment; and
9. The interactions with other farms.

One way to formulate the problem in a manner which makes these factors explicit is in the format of activity analysis, and the methodology best suited for this purpose is that of recursive linear programming. A recursive linear programming model consists of four elements: the activity set, the constraint structure, the objective function and the dynamics of the resources. We will briefly discuss these elements.

Figure 2

Flow diagram of the Thailand model

(version I)

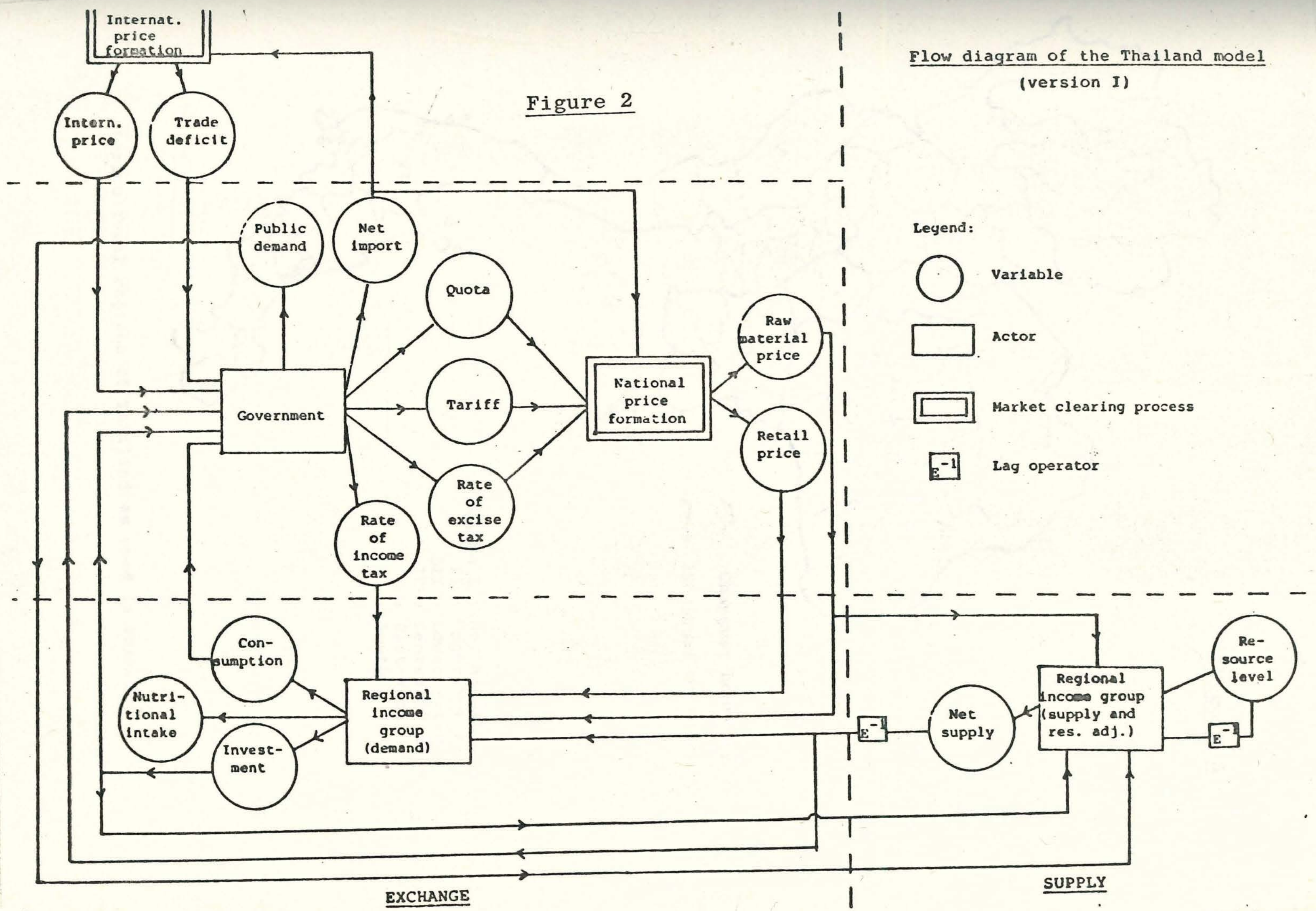
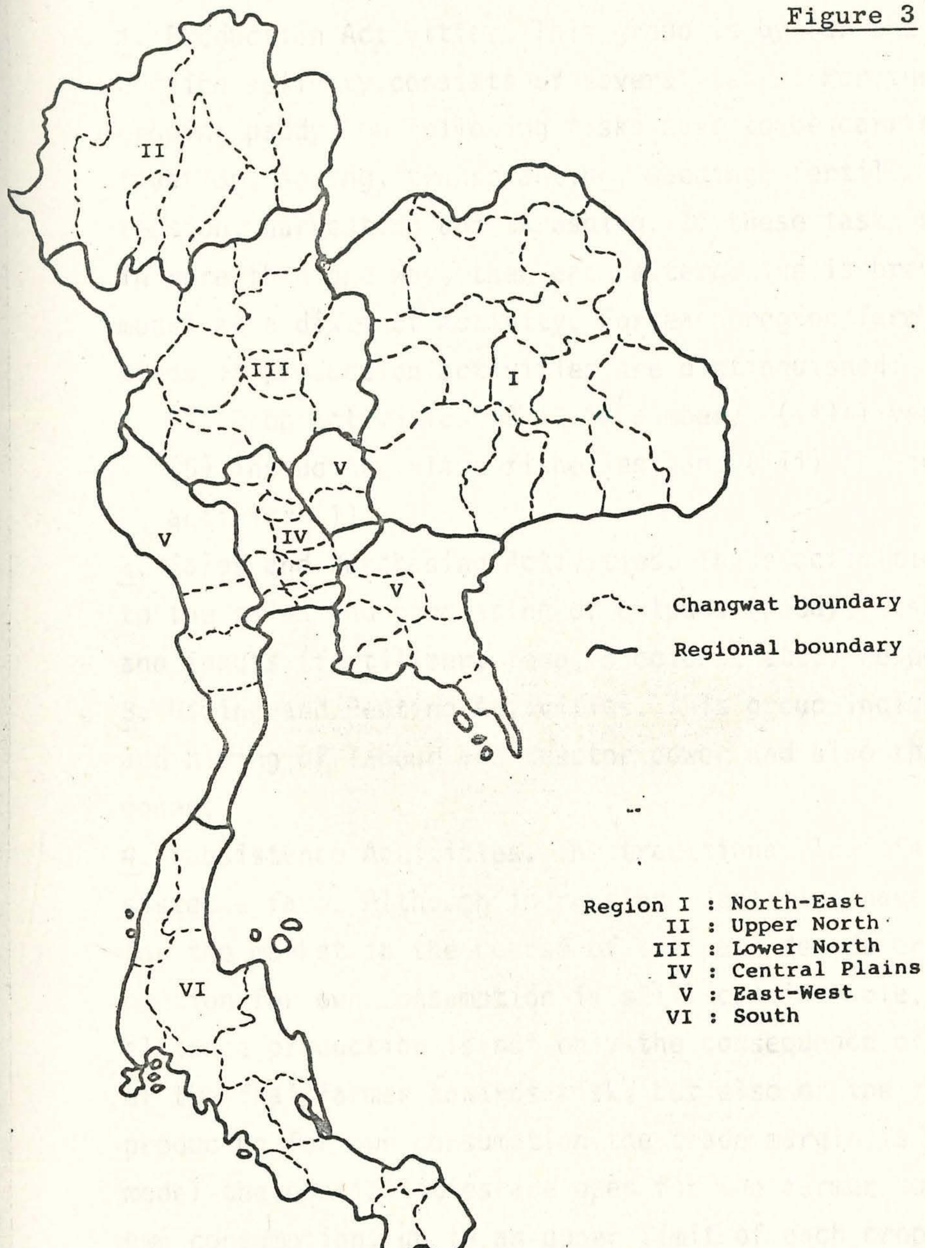


Figure 3



Agricultural regions of Thailand as used in THAM-I

A. The Activity Set

We can divide the activities into six types.

1. Production Activities. This group is by far the largest. A production activity consists of several tasks. For instance, for growing paddy the following tasks have to be carried out: land cultivation, sowing, transplanting, weeding, fertilizing, crop protection, harvesting and threshing. If these tasks can be performed in more than one way, then each alternative is brought into the model as a distinct activity. For each region/farm size, three kinds of production activities are distinguished:

(i) Crop activities (8-12 in number); (ii) livestock activities (5) including inland fisheries; and (iii) non-agricultural activity (1).

2. Sales and Purchasing Activities. These activities are related to the sales and purchasing of outputs (paddy, cassava, eggs, etc.) and inputs (fertilizer, feed, biocides, etc.) respectively.

3. Hiring and Renting Activities. This group includes the renting and hiring of labour and tractor power and also the borrowing of money.

4. Subsistence Activities. The traditional Thai farm is a subsistence farm. Although increasing quantities have been produced for the market in the course of the past decade or so, the proportion for own consumption is still considerable. This subsistence production is not only the consequence of the attitude of the Thai farmer towards risk, but also of the fact that by producing for own consumption the trade margin is earned. In the model the possibilities are open for the farmer to produce for own consumption, up to an upper limit of each crop (e.g. vegetables, fruit, eggs, poultry meat or pork).

5. Migration Activities. Two kinds of migration activities are distinguished: permanent migration and seasonal migration. Both activities refer to migration within the region. Migration to Bangkok is treated in the migration module outside the L.P.Model.

6. Investment Activities. A distinction is made between public and private investment. In the first version of the model investment types take place in the investment module. Ultimately, however, private investment (in tractors, reclamation, etc.) will be included explicitly in the recursive linear programming model.

B. The Constraint Structure

We can divide the constraints into two types.

1. Resources Constraints. The main resources are land, labour, fertilizer, animals, tractors and cash.

(a) In the model six land classes are distinguished: (i) flooded lowland; (ii) rainfed lowland; (iii) wet season irrigated land; (iv) dry season irrigated land; (v) upland; and (vi) permanent fallow + pasture.

(b) Labour is expressed in available hours per month. During the planting and the harvesting seasons is a possibility for making overtime. Labour of children can only be used for cattle and buffalo herding.

(c) Six types of livestock are distinguished: buffaloes, cattle, pigs, poultry for meat production, poultry for egg production, and fresh-water fish.

(d) Tractors. The number of tractors determines together with the number of buffaloes and cattle, the availability of draught power.

(e) Fertilizer is constrained at the national level. Organic manure is expressed in fertilizer equivalents; the quantity is determined by the number of animal activities.

(f) Cash. A certain percentage of last year's income can be used for buying non-farm inputs. The available cash can be extended by means of borrowing from banking institutions. The borrowing capacity of these institutions is regionally constrained.

2. Behaviour Constraints.

(a) The demand for home-produced goods has an upper limit. This upper limit is adjusted from year to year according to a set of demand functions that depend on income and prices.

(b) The flexibility constraints place both upper and lower limits on the extent to which farmers are willing to increase or reduce output of any given crop or type of livestock in response to profitability in the previous year(s). This cautious response is due to

(i) conservative attitude towards change; (ii) a desire for diversification; (iii) the expectation that the profitability may be short lived; and (iv) lack of infrastructure (market channels) which are not explicitly brought into the model.

C. The Objective Function

We assume that the Thai farmer carries out the activities with the following objectives in mind: (1) meet family requirements for food; (2) maintain the production capacity of the farm at least at the same level; and (3) after these first two objectives have been met, try to maximize income. The first two objectives are translated into constraints. The third objective is brought into the objective function of the model.

D. Dynamics of the Resource Structure

Every year the resources (as well as the price expectations) are adjusted on the basis of interactions with the other sectors of the model and the outcome of the production module in the previous production period. Partly these adjustments are exogenous, for instance the increase in irrigated land area till 1990 has been estimated in accordance with the current plans of the Thai government. The change in available labour is the result of population growth and migration. Savings by farmsize group are generated as an output of the exchange module. These savings function as a variable in the investment module, and determine the investments in new farm equipment. In the first version, investments in cattle and buffaloes are exogenous; investments in other livestock are based on expected profitabilities with an exogenously estimated upper limit. The parameters of the behaviour constraints are constant during the time period of the model and estimated on the basis of historical behaviour.

2.4 Data base

To estimate the model, a huge quantity of data was needed. The two main sources of information were:

1. Actual Thai and other (statistical) publications, and
2. Technical data generated by the agronomic submodels. These submodels will be discussed in chapter 3.

3. Agronomic Submodels

This chapter describes the approach and structure of modelling physical aspects which affect the farmers desision making. This model has been developed by the Center's agronomists, mainly located at the Agricultural University and the Centre for Agro-Biological Research in Wageningen.

3.1 The Crop Model

The model of plant production is schematically represented in figure 4. Yield levels depend on the characteristics of crop and site as indicated by the arrows. At the highest hierarchical level it is assumed that all removable constraints are effectively eliminated, leaving irradiance as the sole yield determinant.
At the next hierarchical level the influence of a subsequent factor is considered and other factors lower in the hierarchy are supposed not to be constraining. The other levels have been handled the same way; in some cases there are feedbacks through the hierarchy. Sequentially yield is being used as the independent variable which determines required yield related material inputs and labour.

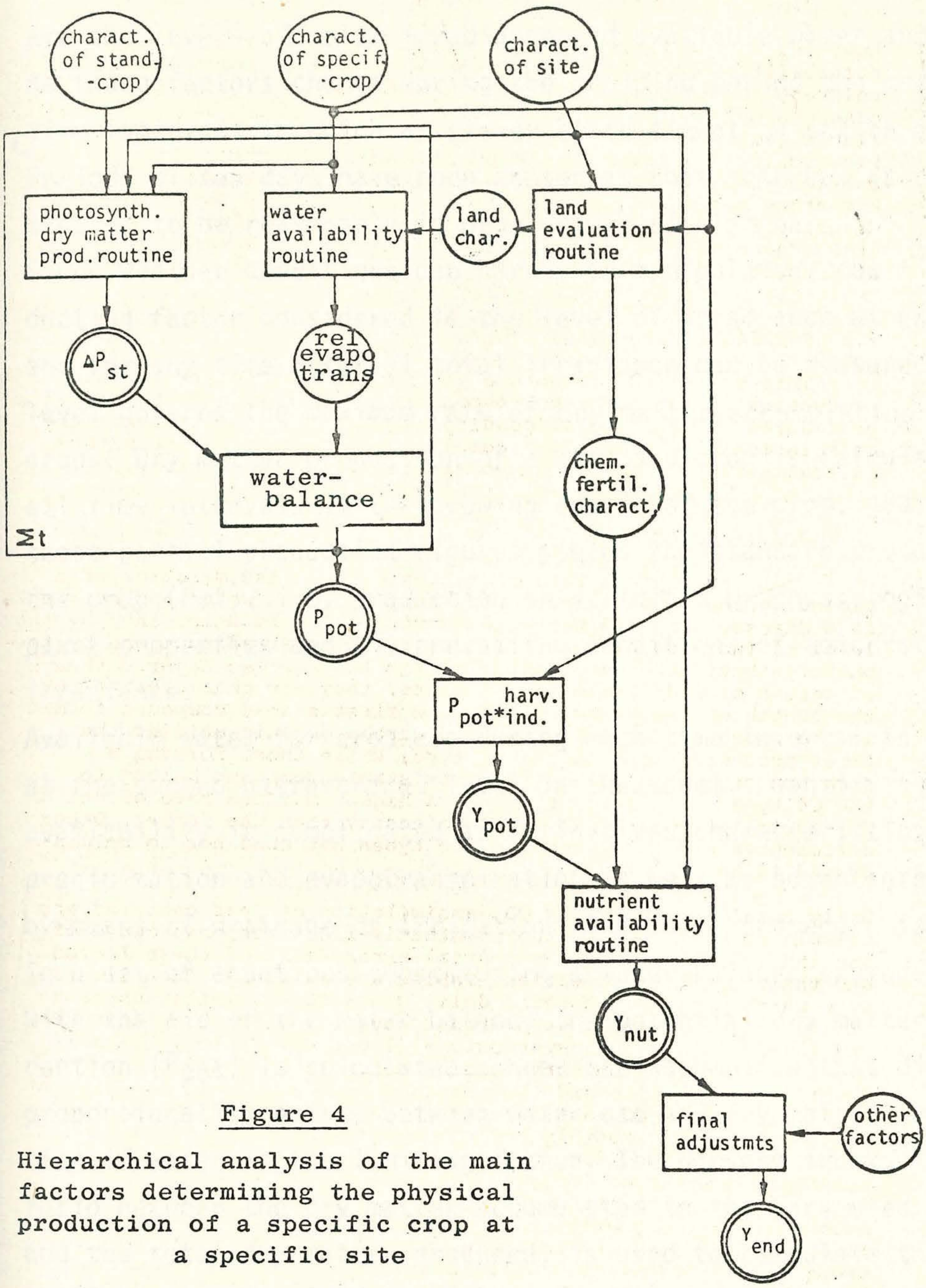


Figure 4

Hierarchical analysis of the main factors determining the physical production of a specific crop at a specific site

p_{st} = standard dry matter production of crops

p_{pot} = potential dry matter production of crops

y_{pot} = potential of economic relevant yield

y_{nut} = crop yield after considering nutrient constraints

y_{end} = crop yield to be used in the LP model.

The main factors influencing crop production on a particular site are the levels of solar irradiance and available water and nutrients. As these factors change during the cropping period the model employs time intervals in which a steady state situation can be assumed. Periods of ten days have been chosen as this interval is considered to be reasonable in crop growth simulation.
Since weather conditions can hardly be manipulated, the first production factor considered is the level of irradiance at each site and for any time interval total irradiance can be measured. Its level governs the maximum rate of dry matter accumulation in crops. Dry matter production of a standard crop is calculated for all time intervals in the growing season of the crop. Addition of these partial production figures yields the standard production of the crop (Pst), i.e. production only limited by physiological plant properties and the prevailing conditions of temperature and irradiance.
Available water for crop use during each time interval is analysed at the second hierarchical level in the model. Quantifying water availability is complicated as it involves characteristics such as precipitation and evapotranspiration as well as human interference by means of drainage or irrigation. The whole procedure is described in a set of equations constituting a water balance submodel.
With the aid of the water balance the potential dry matter production (P_{pot}) is calculated, under the assumption that direct proportionality exists between water use and dry matter production if water is the limiting factor. The harvest index, i.e. the ratio between the dry matter accumulated in the harvested product and the total dry matter produced, is used to calculate the potential economic yield at the chosen site under the prevailing conditions of water availability and under the assumption that all other production factors are not limiting.

This potential yield (Y_{pot}) can be increased by measures of land amelioration that augment the quantity of available water or by breeding new crop varieties which make more efficient use of the available water, or both.

The availability of plant nutrients, notably of nitrogen (N), phosphorus (P) and potassium (K), is analysed at the third hierarchical level of the model. In many systems where fertilizers are not applied, shortage of plant nutrients, particularly nitrogen, limits crop production. A host of experiments on soil fertility, including the effects of manure, compost and artificial fertilizers on plant performance, have been published. Studies on the uptake of NPK by crops and on the efficiency of fertilizer applications are also available. This information forms the basis of a generally applicable method to predict the nutrient response of crops.
The maximum use of partial knowledge is considered the main advantage of the hierarchical approach in modelling crop production. However, the modelling of feedbacks between the hierarchical levels is difficult -sometimes even impossible- which is somewhat of a disadvantage of this approach.

3.2 Regional Aspects [1])

The discussion of the crop production model has so far concentrated on the analysis of physical crop production at a specific site. On a regional basis, however, differences in environmental conditions exist. Even over small areas with a uniform climate, important variations in soils may occur. This means that for every site the various characteristics may have different values. In a country numerous sites must be studied, and it is impossible to run the model for each individual site. Therefore, sites need to be combined and the crop growth model has to be run for each combination.

[1]) This section mainly belongs to the responsibility of Johan Berkhout, Physical Geographer of the Centre for World Food Studies.

This introduces the problem of data aggregation. The following sections explain how data are aggregated and how representative numbers are calculated and used in the model.

Site characteristics.

Site characteristics concern primarily climate, soil conditions and reclamation level. There are three types of data; each type has to be handled in a different way:

(a) Point data, for example those collected by weather stations, are available for a number of sites with a known location. These data represent an area of which the boundaries are not well defined and there are transitional zones for which data must be determined by interpolation.

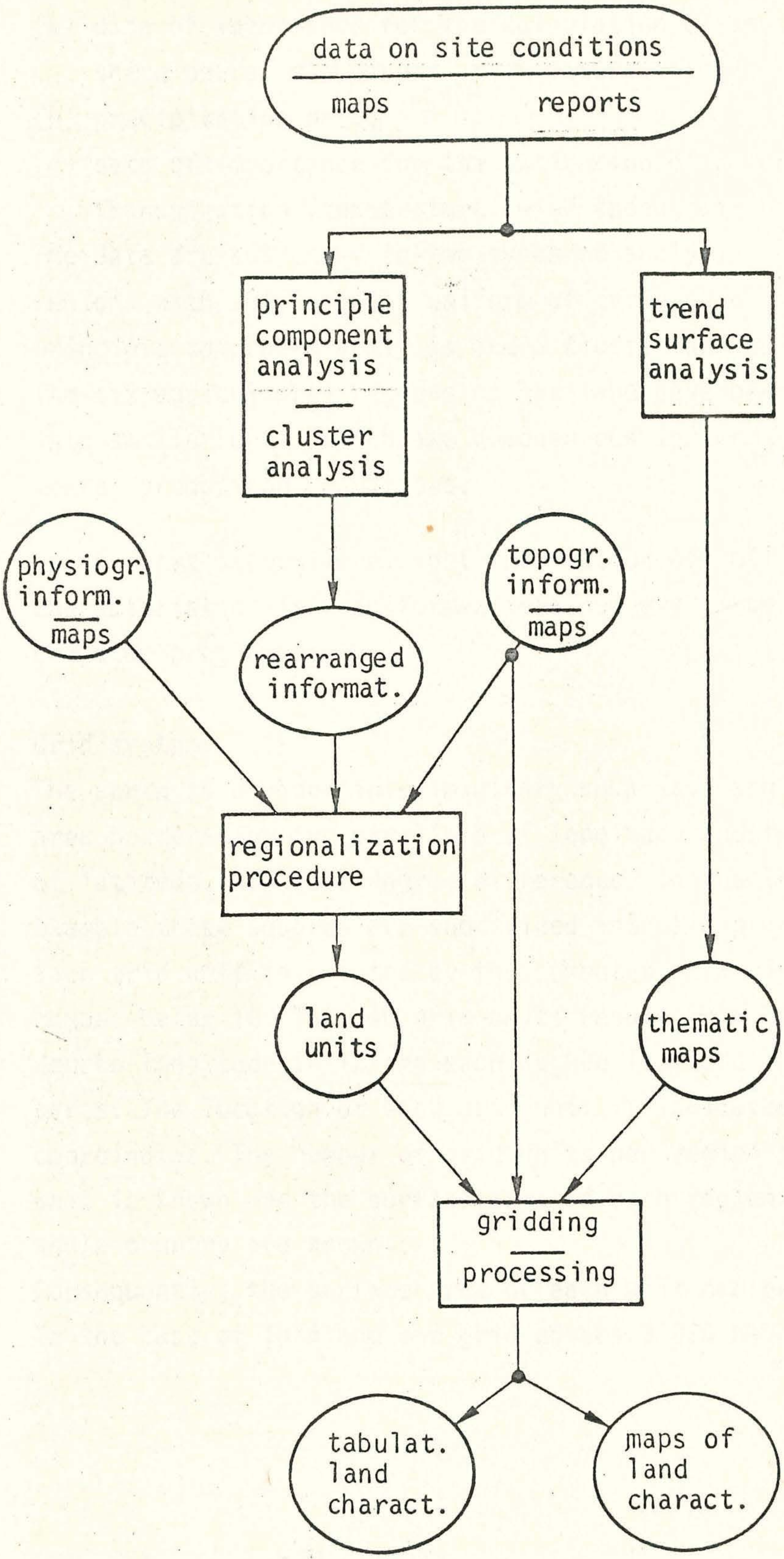
(b) Data on well defined delineated areas on maps. These are commonly already aggregated and are not always available in numerical form. Examples are soil maps, land use maps, etc.

(c) Statistical data. They are commonly expressed in numbers and aggregated per district, region or country such as data on acreages under various crops, farm sizes, number of animals or machines, or quantities of applied fertilizers.

The reliability of all data must be evaluated; their quality determines the degree of detail which can be obtained.

Regions, land units, geographical aspects.

Large areas with considerable variation in size characteristics need to be divided into smaller areas which are reasonably homogeneous. As variations in climate tend to be more gradual than variations in soil conditions, the first step is to distinguish regions which are climatically homogeneous. For this purpose the following monthly data are prepared from information supplied by weather stations:



General outline of the procedure to distinguish land units and to derive land characteristics.

(a) data of importance for the calculation of assimilation (sunshine hours, cloudiness, temperature, etc.),
(b) precipitation data,
(c) data of importance for the estimation of potential evapotranspiration (temperature, wind speed, air humidity).

The data are subjected to two types of analysis to delineate regions with sufficiently uniform climatic conditions, viz. a principle component analysis and a cluster analysis.
The six agricultural regions of Thailand have been subdivided into smaller units which are homogeneous in terms of environmental production conditions.

In the next step all relevant information of soil and climate characteristics is transformed into numbers to be handled by computer programmes.

Grid system.
The earth is divided into imaginary squares, each covering an area bordered by two parallels of longitude and two parallels of latitude, with one degree difference. In the Thailand example these squares are subdivided into 240 grid units. Each grid unit is printed by the computer as a digit, i.e. a number below 10. The 240 grid units result from dividing each degree longitude in 12 and each degree latitude in 20 equal parts. The location of each grid unit is indicated by its coordinates. The number of grid units per region and per land unit is known and the surface area of each region and of the whole country are known.
Consequently, the surface area of each unit can be computed. In the case of Thailand one grid covers 3 030 ha.

Climate characteristics.
Climatic data are used to calculate Pst in the submodel of carbon assimilation. In the submodel of water availability these data are required to calculate evapotranspiration. The regional variation in climatic characteristics over the various grid units is established by means of a trend surface analysis based on data from weather sations.

Soil characteristics.
Data on soil conditions are needed for the water balance to estimate P_{pot} and for the nutrient submodel to determine Y_{nut}. Relevant information is extracted from soil maps and reports. If two or more soil associations occur within one grid unit, the fractional coverage of each association is estimated. It is then determined which associations occur in each land unit and to what extent they occupy the unit. The areas calculated are gross areas because they include also land that is not used for agricultural purposes. The transformation of gross areas into net areas is performed by means of statistical data. The main soil parameters used in the model are: soil texture, soil organic matter, soil nutrient stock and soil profile development.

The output of the crop-model consists mainly of technical coefficients which describe discrete yield-to-input and yield to resource relation. The program which connects the cropmodel with the economic model is called "linkage interface". In the Thai model as it stands linkage has been done manually and on once-for-all basis. The interface program has now been completed and will be used in next versions.

3.3 Livestock Production

Coëfficients of livestock production have not been derived from a model of growth simulation but are based on both Thai specific and general literature on feeds and animal nutrition.
The livestock and crop production sectors have been linked via animal traction, production and use of manure and feed requirements. In figure 5. these relations are represented schematically.

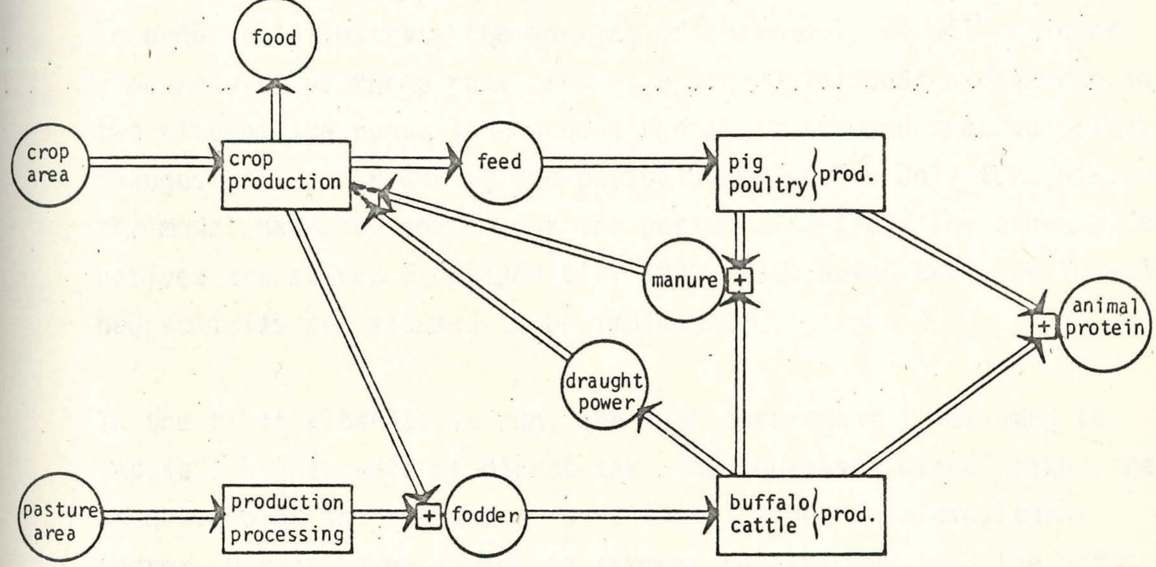


Figure 5: Diagram of physical flows in the crop-livestock farming system.

Pigs and poultry use crop residues such as bran, hulls and shells. Ruminants use straw and roughage and graze on fallow and waste lands. Cattle and buffaloes produce dairy products, meat, manure, draught power, etc. Interactions among farm sizes manifest themselves in the exchange of labour. Small farmers offer surplus labour to large farmers; large farmers hire out surplus tractor hours to small and medium farmers, particularly during the land preparation season. Moreover, small farmers exploit relatively more communal grazing land.

This results in a higher cattle density on small farms which may explain some of the difference in yield level between small and large farms.

4. Some Results

The model is constructed for the specific purpose of analyzing the effects of various policies on agriculture – in particular the impact of such policies on different farm groups within and between the regions. In order to illustrate the working of the model, we will discuss some results of three runs that have been developed: a base run and two alternative runs. In the base run it is assumed that no policy changes will occur during the period under study. Only for this run the model has been solved for the period 1973-1989. The other alternatives are solved from 1980 till 1989, 1980 being the year in which new policies are assumed to be implemented.

In the first alternative run, the Thai government is assumed to impose a higher rate of direct tax. The increased direct taxes are levied on households and private corporations in the non-agricultural sector. Direct taxes levied on farmers remain very low. The effect of such an increase will be that direct tax revenue increases, indirect taxes decreases, consumption of non-farm households will decline and consumption as well as caloric intake of farmers will increase.
The other alternative policy assumes that the non-agriculture import duty decreases over time. This will cause a decrease in the domestic price of non-agricultural commodities. Consequently the terms of trade change in favour of farm households. Consumption of farmers rises and consumption of non-farmers declines. Total consumption of non-agricultural commodities increases in line with imports

Under the base run the average growth rate of real GDP (graph 1) reaches 5.9 percent, both during 1973-1981 and 1981-1989.
The growth rate of population is estimated to be 2.5 percent

per annum, resulting in a per capita growth rate of GDP of 3.4 percent. When direct tax rates are increased, the overall economic rate of growth is slightly lower at 5.6 percent. The lower rate of growth arises from the lower savings generated by the economy – these are taxed away – and therefore lower investment. In the import tariff alternative, the overall economic rate of growth is also slightly lower than in the base run, 5.8 vs. 5.9.

Throughout Thai history rice has been one of the main export products. In graph 2 export projections are given under the assumed policies. Differences are quite remarkable. For the period 80-89, the base run predicts a decrease in rice exports of .5 percent per year,while the increased direct tax run shows on average, a decrease of 1 percent per year. In the 'import tariff' alternative, on the other hand, a yearly increase in rice exports of 3.4 percent is expected. Export performance is better for all agricultural products in the 'import-tariff' run. Because of a lower price for non-agricultural product, use of inputs (fertilizer!) becomes more attractive which results in a growth of exports. Farm exports also grow in order to pay for increased non-agricultural imports, given a fixed trade deficit.
In graphs 3, 4 and 5 interregional income development is shown for agriculture in the Northeast and the Central Plain.

In all three runs income per capita grows faster in the Northeast than in the Central Plain. Because of the income disparity in the base year (in 1973 per capita incomes for the Northeast and the Central Plain were 1926 and 3620 Baht respectively), this means that relative income differences decline.

Per capita income grows in all cases except for the Central Plain farmers in the base run. Differences in growth among the alternative policies are quite substantial. For the Northeast farmers income increases by 17.6, 59.6 and 75.0 percent respectively over the period. With regard to the Central Plain, income growth amounts to -2.8, 35.1 and 29.8 percent in the respective runs. So if we take into account that (a) incomes in agriculture are on average much lower than in non-agriculture, and

(b) the Northeast is by far the poorest region, a policy directed at narrowing income differences will be more successful if import tariffs are decreased than if current policies or a policy of increasing direct taxes are applied.

Indices of income development within the same region are shown in graphs 6 and 7. As could be expected (see graphs 3 and 5), both farm groups do much better under a policy of decreased import tariffs than under policies specified in the other runs. It is interesting to see that income growth of the small farmers, on a per capita base, in both cases exceeds income growth of the large farmers. In the base run during 1980-1989, income growth of small farmers is 52 percent, while large farmers grow 'only' 36.6 percent. The alternative run (decreased import tariff) predicts, for the same period, an increase in income of 102 for small, and 84 percent for large farmers.

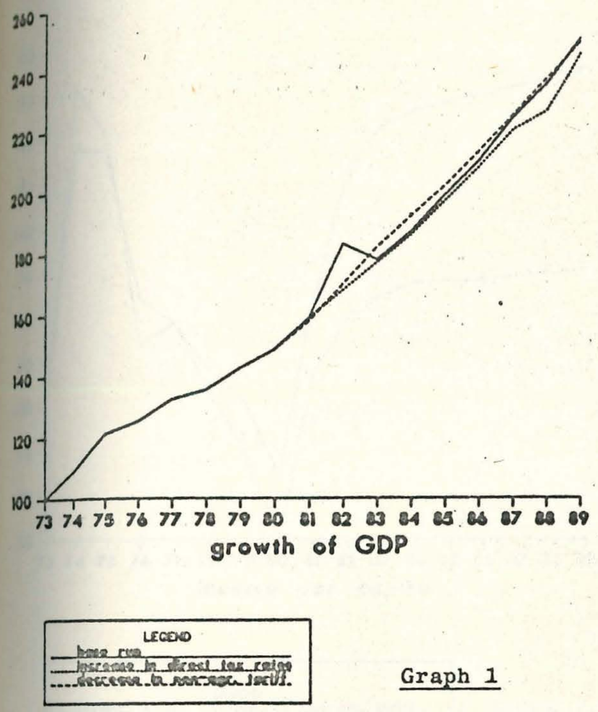
The model generates for each income group a demand for food and non-food commodities. To have an idea of the nutritional status the food demand is translated in terms of calory and proteins. In graph 8 the average calory intake of the Northeast is compared with the national average under the base run. While the national average intake grows 30.1 percent to 2975 calories, growh in the Northeast is only 6.6 percent totalling 1820 calories. The latter means that in the Northeast inadequate nutritional intake will be a frequent occurence during the projection period.

- - -

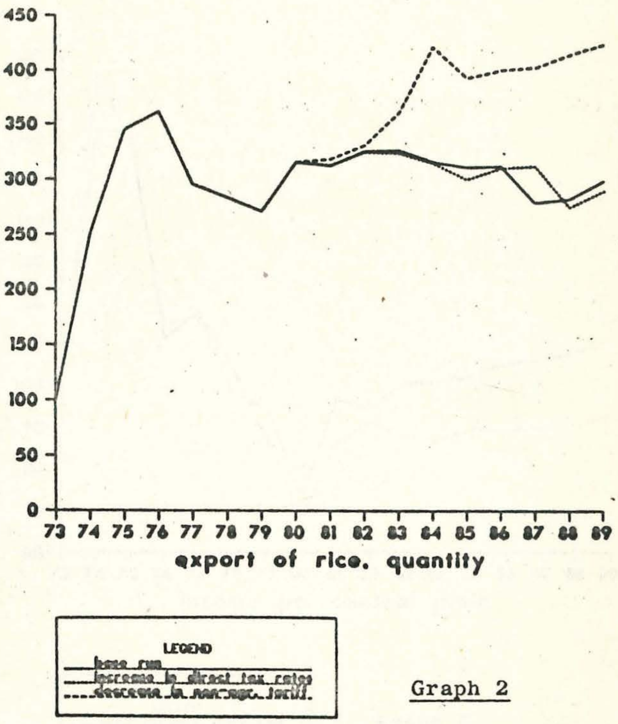
Research and documentation on Thailand is reported in the research reports SOW-80-1 to 5, as follows:

1. Food and Agricultural Model for Thailand, THAM-I.
2. A Summary Description of the Thailand Agricultural Model, THAM-I.
3. A Social Accounting Matrix for Thailand, with Special Reference to the Agricultural Sector.
4. Data Base of the Agricultural Supply Module of THAM-I.
5. The Model of Physical Crop Production.

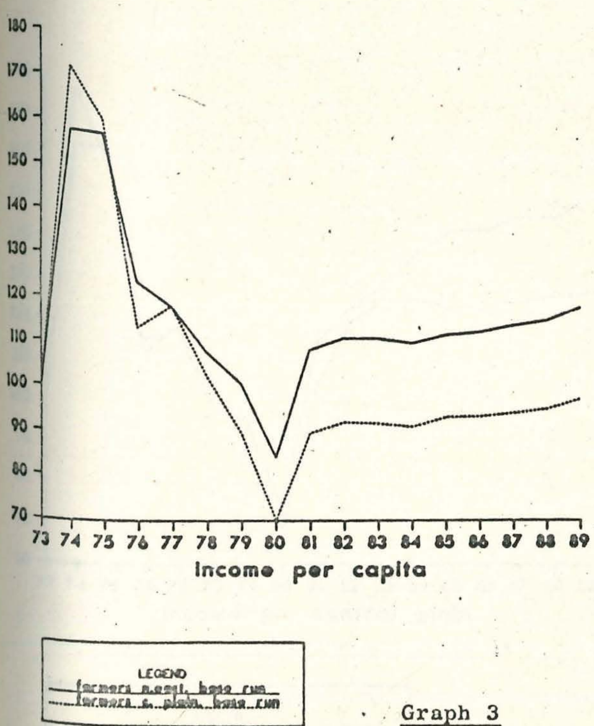
Address: Centre for World Food Studies, P.O. Box 7161, 1007 MC Amsterdam, The Netherlands.



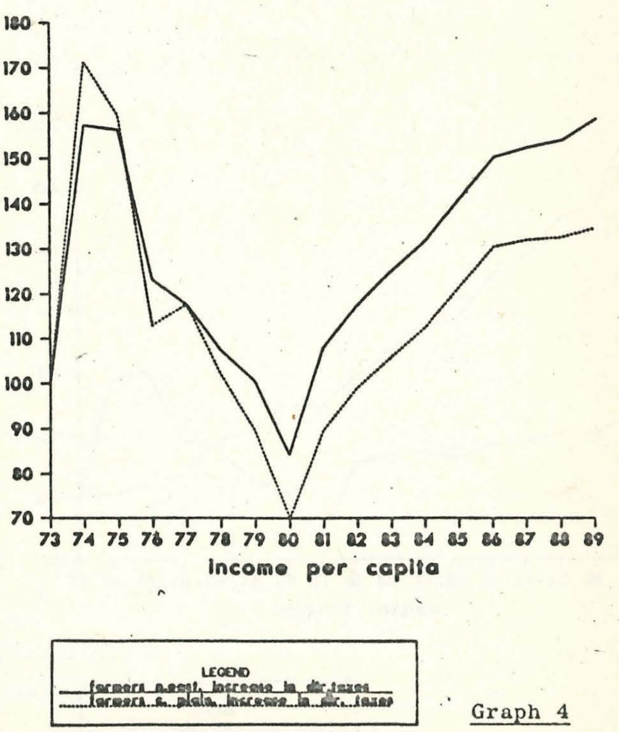
Graph 1



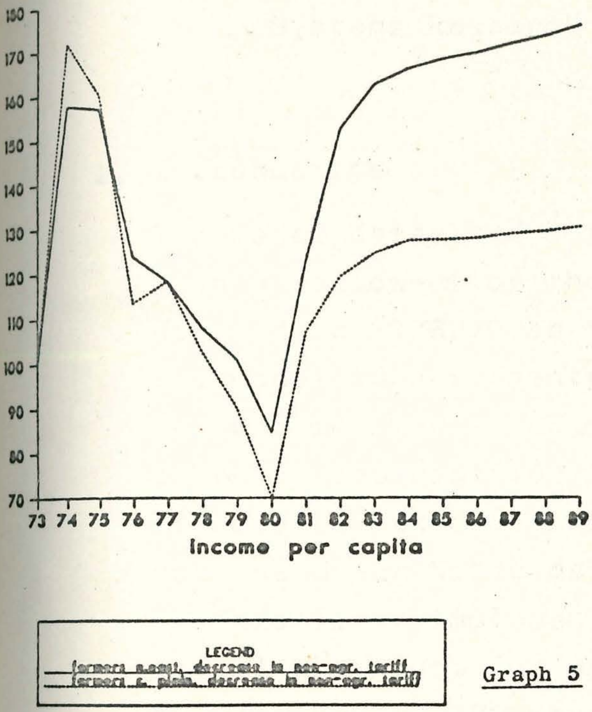
Graph 2



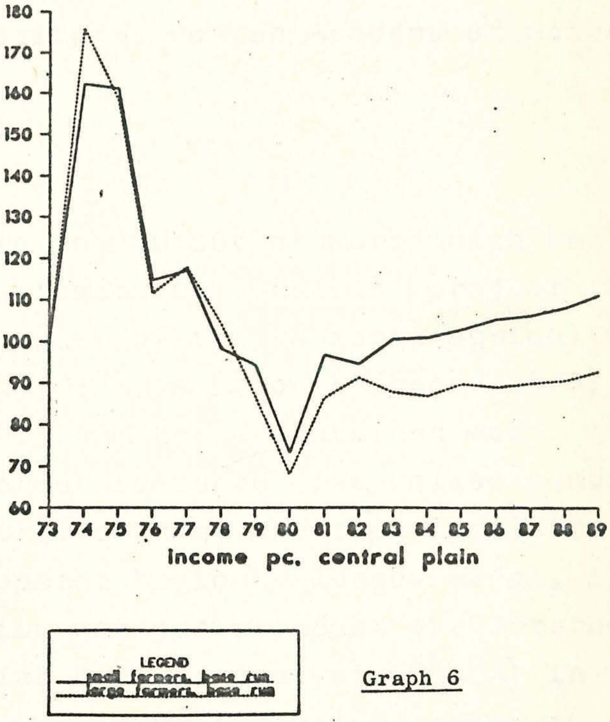
Graph 3



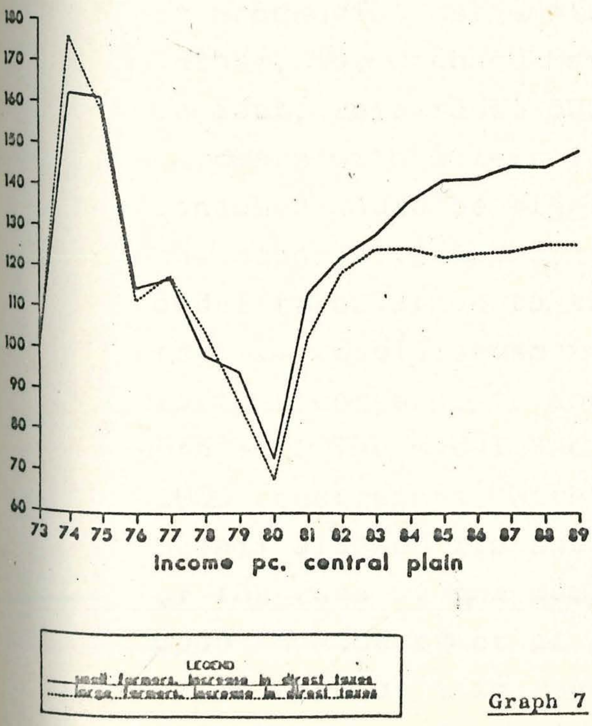
Graph 4



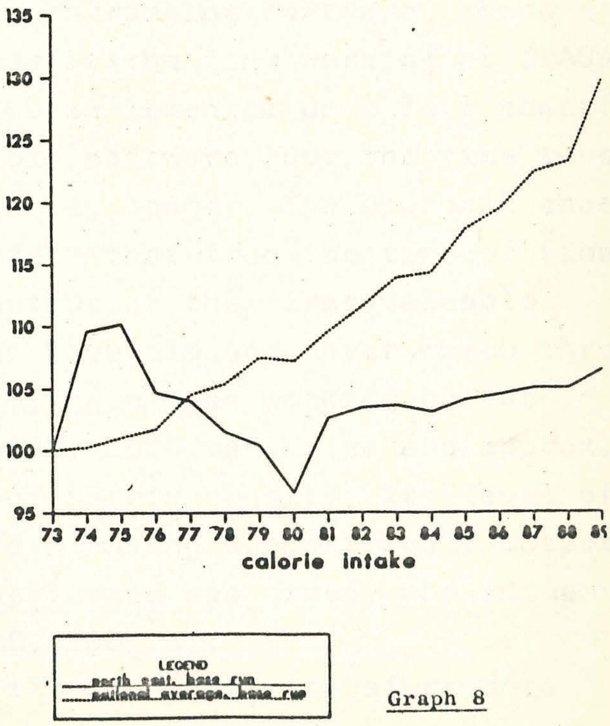
Graph 5



Graph 6



Graph 7



Graph 8

TWO-LEVEL MODEL OF REGIONAL AGRICULTURE
APPLICATION TO THE UPPER NOTEC REGION IN POLAND

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1. Introduction

The model described here is the output of work which has been a follow-up of the agricultural modelling project started in 1978/79 on the basis of the regional agricultural model idea presented by M. M. Albegov (Albegov 1979). The outline for an LP model GRAM there contained was taken up and modified in order to better fit Polish conditions of a mixed agricultural economy and then impulemented for the Upper Noteć development region (Albegov et al. 1981).

This first implementation was performed at the International Institute for Applied Systems Analysis (IIASA) in 1979/80 on IBM 370 in the CNUCE/IBM computing center in Pisa through the connection from Laxenburg. The main reason for such approach was existence in this computing center of a powerful mathematical programming software, whose author, Wm. Orchard-Hays was at the time working at IIASA. In fact, this model could be implemented on a less powerful hardware with a less flexible software, but the time thus consumed would be significantly longer. The approach chosen has been justified by the fact that from the time of final model formulation to the output of the first valuable results merely seven months have elapsed, over which three to five persons, on and off, have been working on the project. The model had approx. 3500 variables and approx. 1000 constraints, with 2% of matrix density. Its level of detail allowed its use as a planning support tool. Output of the runs of the model performed was given, and commented upon in Albegov et al (1980, 1981 a).

In view of this result the model was transferred to Poland in the form of the ready data matrix in order to test the feasibility of its running in Poland. The test had been successfully performed in the summer/autumn 1980 on a modest IBM - compatible RIAD-22 computer equipped with the equivalent of MPSX mathematical programming package.

The results obtained as well as needs of planning for the Upper Noteć development program have contributed to the extension of the contract with the Institute of Land Reclamation and Grassland Farming, acting as the coordinator within the governmental program PR-7 (see Somorowski 1981), under which the work was carried out in the Systems Research Institute. Together with the contract extension some additional specifications as to the role of the model were made, concerning especially furthering of its level of geographical detail. These specifications of necessary fine tuning of the model resulted also from the meeting in spring 1980 at the Bydgoszcz voivodship office during which planners and the then administrative decision-makers were shown results of GRAM. It should be noted that the Bydgoszcz voivodship accounts for the major part of the Upper Noteć area. The meeting confirmed the status of the model as a region-wide policy and plan preparation supporting tool, and allowed the customers to formulate requirements as to modifications.

Simultaneously, some additional customers in the country have appeared, interested in application of a similar model to other regional agricultural systems. Their main problems were somewhat different from those encountered in the Upper Noteć basin.

Thus, continuation of work on the regional agricultural model had to be closely connected with important modifications in the model structure.

It should be emphasized that the modifications mentioned would not alter the fundamental modeling assumptions concerning Polish agriculture, formulated in 1979 (Albegov et al. 1981b) , which served in developing GRAM and are kept to in its extension. Moreover, recent changes in functioning of Polish economy, and further anticipated changes fully justify these assumptione made at the start. It is the realism of these assumptions, stipulating explicit consideration of various producer types and natural and economic conditions in which they act, that had ensured increased applicability of the adopted model structure. Some remarks on that subject will be contained in the following section.

2. Purpose and implementation assumptions: base and extensions

The regional agricultural model is meant as a plan preparation supporting tool for a regional decision-making body, such as administrative planning division, local bank management, producers association, or project management. It would provide a planning division or any other body acting within the regional decision process concerning agriculture with two types of results: first, an optimal solution, i. e. specification of the system's state which is both desired from the point of view of a certain quantitative criterion, and feasible from the physical and financial points of view, and second, the means to achieve this, optimal, system's state, together with the effectiveness of these means.

The feasibility of the optimal system's state solution depends on the physical conditions of resource availability and on the relative advantage resulting from the solution for other actors-participants of the overall decision process, primarily producers. Thus, it is obvious that the feasibility aspect of reactions of the other decision meking actors accounted for while determining the optimal solution has to be weighted with the aspect of controllability with regard to these actors when establishing the capacity of bringing about the optimal system's state. It may namely be nonsensical to define optimal solutions which are clearly relatively disadvantageous, in comperison to other feasible ones, to those actors who shall shape the actual state of the system while control capacities over these actors are small.

Because of these built-in inter-actor feasibility assumptions the extension of GRAM can be used in various socio-economic settings. Such approach was clearly conditioned by fitting to Polish agricultural structure not only complex in itself, but also regionally variable in its mix of land ownership and production technology types. Another important assumption which resulted thereof was adoption of both material and financial "accounting", as two inseparable aspects of any economic system, whether in the so-called market or planned economies.

The two types of basic assumptions mentioned should allow the use of the model as a debate tool in the decision process, making it possible to rationally present and justify various claims on volumes, prices, credit schemes, preferences etc. by various decison making actors. In particular, the main actors aimed at with the model should find it possible to formulate with the model runs their stances with regard to central administration, other sectors of economy and the direct producers therein, as well as among themselves.

These features of the model gain especially in importance in view of the economic mechanism changes that Poland is now undergoing. These changes will place all the producer types on an equal - efficiency based - footing with regard to prices, resource distribution and credits. Producers in the state sector shall also get more of the activity freedom, togother with greater financial responsibility. Simultaneously, "grass-roots" mechanism have been called for in local administration and monitoring. Thus, more face-to-face coordination among actors having various values will have to take place. All this is in agreement with either assumptions of GRAM and its extension or with conclusions from the first GRAM runs (Albegov et al. 1981b).

Local nature of the systems described with the model, both sectorially and geographically, does preclude contry-wide rationalization of prices, although out-put of the model may certainly serve as a yardstick for a price structure.

In order to be used as a practical planning tool the model has to depict the system with sufficient detail regarding such entities as crops, livestock, natural resources such as soils, water etc., equipment, producer types, geographical breakdown elements and the like. The principle should be kept to that the magnitudes appearing in the model have real counterparts rather than abstract interpretations.

Thus, it is assumed that agricultural activities depend upon such factors as availability of nutrients, soil quality, fertilizers, crop rotation, feedstuffs, water, air, agrotechnical operations, storage, processing and transportation facilities, and that these dependencies should be accounted for in as much as they influence farming decisions being made. Such decisions do in fact shape the overall state of the regional agricultural system.

These farming decisions mentioned tend to be similar for similar conditions and they are made on the basis of only such "global" data as prices, otherwise they are made on the basis of such local data as yields, resource, particularly when significant shares of non-transportable goods (e.g. some feedstuffs) come into play. Thus, producer types and subregions come forward as important distinguishable entities.

The application and structure prerequisites of the model presented above are in a way summarized in Table 1.

Table 1. Objects and outputs of the model, together with interested actors and their objectives.

LEVEL	NECESSARY OBJECTS OF MODELLING	ACTORS INVOLVED	OBJECTIVES	OUTPUT
Subregion	Local producer type economy Crops Livestock Soils Other resources Financial flows Technologies	Producer type association Enterprise Local administration	Economic /resource/ efficiency Economic effectiveness	Optimal, i.e. best, and physically and financially feasible, program of activity
Region	As above + Intersubregional distribution of resources + External demand	Producer type Regional administration Banking system Water project management or water system authority	Economic surplus Economic capacity Financial efficiency Economic effectiveness	Optimal policy /resource distribution/ rules
Nation	As above + + Prices +Interest rates + Supplies	Producer type Ministry of agriculture Ministry of finance Supply producers State price commission	Economic capacity Nutritional balànce Financial efficiency Economic effectiveness /Socially justified/ demand/ supply balance	Optimal policy /resource allocation rules, prices, interest, rates, legal mechanisms/

The output contents, flagged in Table 1 with headlines: "Optimal program of activity" and "Optimal policy" can be broken down into the following categories, either obtained directly with an LP Solution, or deduced via more elaborate analyses:

1. Specialization/structure of production, where specialization concerns various producer groups in their production orientation, presented through full structure of their activities,
2. Interproducer cooperation conditions (exchange of products and competition for resources),
3. Resource efficiency, leading to establishment of quasi-production-functions for the most important resources, as well as to resource distribution schemes,
4. Economic vs. "physical" policy orientation distinction, both control-wise, i.e. fiscal vs. resource rationing controls, and goal-wise, e.g. seeking of food supply or financial soundness objectives, and consequences thereof,
5. Industrial and capital inputs vs. agricultural outputs, i.e. provision of debate tools for dealings with other sectors,
6. Self-sufficiency vs. exchange alternative, checking the consequences thereof,
7. Equity vs. efficiency, study of feasibility and policy effectiveness.

For the sake of illustration let us outline some result categories, according to classification given above.

Thus, Figure 1 gives a schematical view of the present and postulated cooperation structure for private and state farws. The situations depicted are rough averages of the ones prevailing now in various subregions, and those postulated for them. As can be easily read out of the figures, the model proposes far stronger specialization cooperation than existing.

With regard to equity vs. efficiency issue a typical income-per-capita diagram for various producer groups when a global net income objective is optimized is shown in Fig. 2. According to anticipation, global efficiency

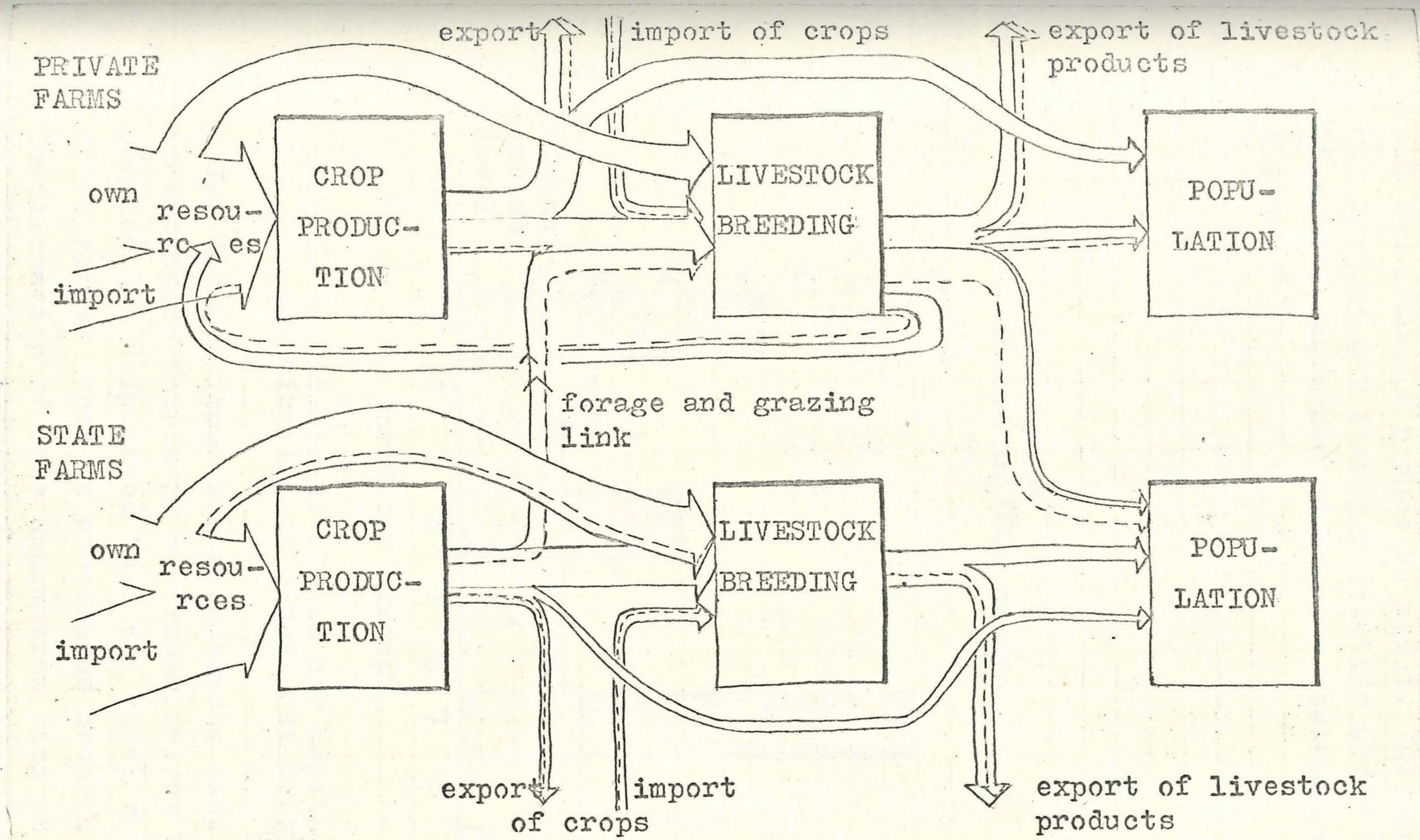

Fig. 1. Present and postulated outline of production linkages of state and private farms on local level. Width of arrows denotes flow volume

: present flows, : future postulated changes decrease / increase optimization yield important income inequalities. Hence, an experiment was performed in which a constraint was set stipulating that attained average incomes per capita in all the producer groups be equal. The model, however did not produce any feasible solution under this constraint. Thus, only paretian constructs could be proposed for the system.

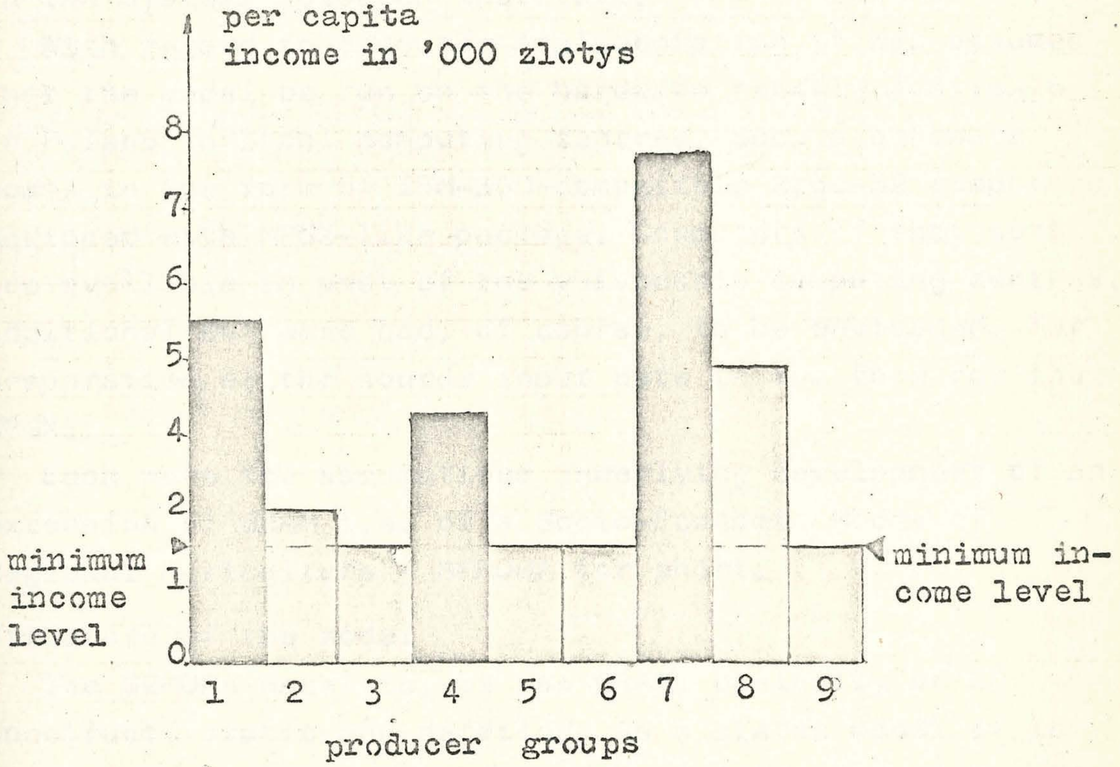

Fig.2. An example of income per capita distribution for maximization of global net profit.

Two further important assumptions made both in GRAM and in extension should be mentioned. First concerns crop production and stipulates that the model refer to individual crops rather than to predefined crop rotation sequences. Justification of this assumption lies in the doubt whether in general a strictly determined crop rotation sequence is an appropriate object of decisions, especially in changeable weather and yield conditions over several years, and also in the territorial stretch of the area being the object of modelling (a region divided into subregions). Second assumption consists in deliberate dropping of explicit transportation costs, as well as processing activities, so that agriculture is regarded as a collection of primary producers who cooperate on a local level, and whose transportation costs may, under previous assumptions, be made implicit as shares of overall farming costs. Additionally, it was assumed that the transportation, storage and processing sector shall be taken up by another, specialized location-and-transportation model. Such a model meant for cooperation with SEMORA is in fact being developed now in the Systems Research Institute.

With regard to computer implementation it was assumed that the model be run on the hardware readily available in Poland in local computing centres. Such a hardware comes in the form of IBM-360-compatible Riad-32 computers equipped with MPSX-like package. Computers of that sort are available in most of the voivodship computing centres. Additional software had, of course, to be envisaged, for preparation of the source input data in the form for the MPSX.

Such were the assumptions underlying development of an extension of GRAM i.e. of a Socio-Economic Model of Regional Agriculture - SEMORA for short.

3. Structure of the model

The SEMORA model is, as was GRAM, basically an LP construct, static and detailed. As a static model it is meant to depict an average year out of a medium-term planning period, say - 4 to 6 years, the year depicted providing an image of the optimal development direction. Dynamic formulation was rejected not just on the grounds of complexity, but primarily because of the great sensitivity of its output to random phenomena, which can be avoided in the case of a static model. The reasons for being detailed ware given before.

In accordance with the previous remarks describing assumptions made throughout the model it was decided to divide the region under consideration into subregions and set up a distinct submodel for each of the subregions. Such procedure accounts for local closure of the interproducer-type cooperation, local market, supply, sales and transportation conditions, as well as local natural resources, making it possible to internalize all of these in the submodels. In an extreme case a region may of course be composed of just one subregion.

To illustrate an aspect of the rationale behind the model decompositon some data on the LP matrix dimensions are given in Table 2 below.

Table 2: Data set sizes of GRAM implementations

CASE	DATA SET SIZE in number of non-zero elements of LP matrix	NUMBER OF SUBREGIONS	NUMBER OF PRODUCER TYPES
1. NOTEČ Ist VERSION	55 000	3	3
SILISTRA	10 000	10	1
2. NOTEĆ IInd VERSION /SEMORA/	12 x 25 000 REPETITIVE + 1 x 5 000	12	3
3. NOTEĆ, IF Ist VERSION	approx. 1 x 160 000	12	3

The submodels comprise balances of such resources as: land - according to producer-type-ownership, soil qualities, crop rotation requirements and availability for second crop; manpower; water; fertilizers, including natural fertilizers obtained from own farm economy; pulling power, including that of the own livestock, which can be used; and money. Besides that the submodels contain natural product balances as well as those product balances which define product purchase and sale volumes. The latter type of balances is meant for two purposes: first, control the throughput of the system within the model, and second, to provide the processing-and-transportation model with adequate information. More detailed description of the entities appearing in SEMORA and its precise structure are given in the Appendices.

As mantioned, assumption is made throughout the model that price levels are given, at least as alternative scenarios. It should, however, be mentioned, that with the level of detail kept to at the lower level the submodels can be used as price-and-activity optimizing constructs when complemented with demand functions. The submodels will have to be got rid of the financial constraints, transferred to the objective function, the later becoming bilinear, the submodel therefere run in the quadratic programming mode. The submodel analyzed should then be treated as a representative of a bigger population, whose elements can in reality vary importantly. Appropriate changes will therefore be made in the interpretation of the upper-level model.

Most of the resource and activity constraints close on the subregional level so that the upper-level, regional model is much less complex than subregional /sub/models. In fact, the main connecting factors for the submodels are: objectives of regional actors and a few of the resources, naturally or societally distributed among subregions, such as water, money, or ready investment inputs.

It is at this level that the most important regional decision-making actors, such as agricultural banks, producer associations, water project management or governor's office can determine their course of sction in resource allocation. These bodies shall take decisions based upon various allocation criterie, whose values can, however, be reconstructed from the output of the submodels. The latter fact, again, emphasizes the role of this model as a debate facilitating tool.

In connection with the above it should be noted that while most of the resources can simply be summed over subregions, this is not the case with water. Because of the particular features of this resource a large portion of the upper-level model will in fact, constitute an inter-subregional water resource balancing model (see Makowski 1980). Instead, an appropriate linking procedure might be used (see Gutenbaum, Makowski, Owsiński 1980).

The outline of the resulting overall model structure is shown in Figure 3.

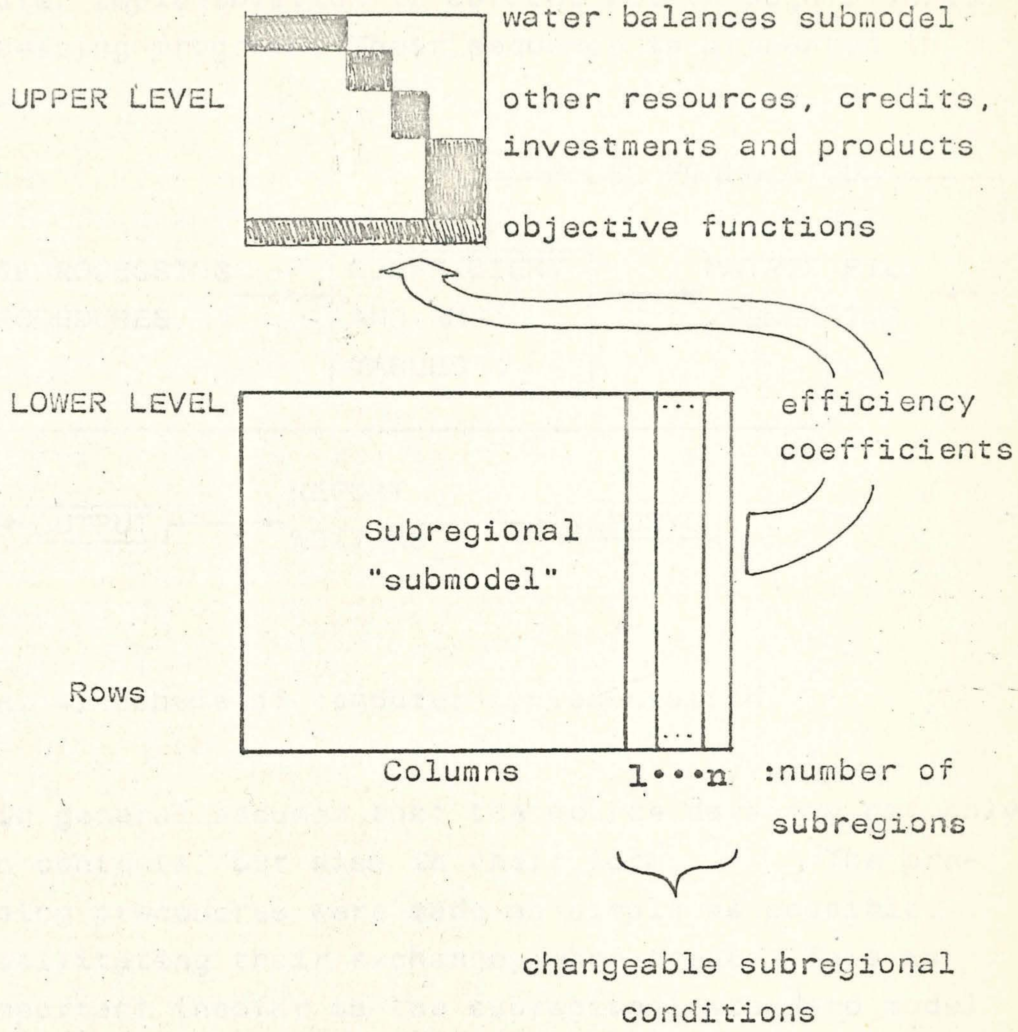

Fig. 3. Scheme of model cooperation and relative dimensions.

The numbers characterizing the outline of Fig. 3 are as follows: n = 12, which is the number of partial-watershed-based microregions agreed between the water construction design office and water system developer (Makowski 1980),
number of columns in the lower level model: approx. 1500,
number of rows in the lower level model : approx. 500,
number of columns in the upper level model: approx. 300,
number of rows in the upper level model : approx. 60.

4. Computer implementation

Computer implementation is carried out through a series of processing programs. Their sequence is presented in Fig. 4.

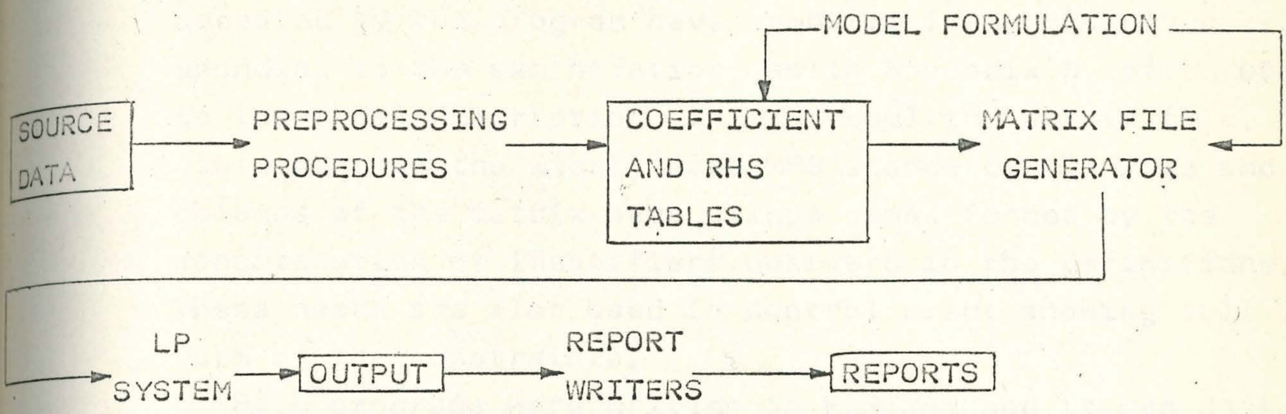

Fig. 4. Scheme of computer implementation.

It is in general assumed that the source data may not only vary in contents, but also in their form. The pre-processing procedures were made as simple as possible, thus facilitating their exchange, when needed. This is very important insofar as the subregional standard model would consist of approx. 1500 variables and 500 constraints, which with approx. 3% density makes about 23000 non-zero numbers to be processed for each submodel setup.

The matrix file generator was on the contrary made flexible in itself since it was anticipated that introduction of changes into this program will be cumbersome and at the same time it will have to serve models of various forms.

The generator has, naturally, two sorts of inputs: the formalized model structure and the processed data set in the form of appropriate tables. In order to absorb the model structure the generator had to be equipped with a simple language-interpreting procedure, with the model structure being presented in this language. This enables absorption of various forms of models and provides for flexibility of the generator. The model formulation entering the generator program begins with the definition of indices, decision variables and coefficient tables occuring in the model description. Then, according with further instructions, the coefficient and RHS tables would be read from the prepared file and stored. Constraints and objective functions accepted by the program have symbolic form, closely corresponding to the sum notation, as in Appendix B, often used in the model description. In the resulting matrix file, conforming to the widely used MPS standard, all rows and columns of the matrix have unique names formed by the concatenation of identifiers deliverd in the definitions. These names are also used in control print showing full form of the constraints.

Both programs were written in FORTRAN and it was decided not to use the MPSX or ther systems facilities with that respect so as to retain the flexibility. Report writers are meant to produce a summarized version of output and, at the moment, the ones belonging to system facilities are used.

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Appendix A: Notations

Indices denote /in the sequence of their appearance/:

i - crops, $i \in I = \bigcup_{W} I^{W}$, $I^{W'} \cap I^{W''} = \emptyset$, card I = 16 for Upper Noteć

w - crop rotation group index,

s - crop technologies, s = 1, 2, 3

p - producer types, p = 1, 2, 3

α - soil quality types, α = 1, 2, 3, 4

r - subregions, r = 1,...,12

β_i - subsets of indices of secondary crops following i-th crop,

γ_i - subsets of indices of first crops appearing before the secondary crop i,

l - types of purchase and sale market, l = 1, 2, 3

j - livestock animals, j = 1,...,12

m - livestock products, $m \in M = M1 \cup M2$, M1 : slaughter products, M2 - continuous products, card M = 13,

s' - livestock technologies, s' = 1, 2

n - feedstuff elements, n = 1,...,11

f - types of fertilizers, f = 1, 2, 3, 4

η_{t_k} - subsets of indices i, j and m grouped for purposes k.

Variables:

$X_{ips\alpha(r)}$ - areas under crops i, owned by producers p, cultivated with technology s, of soil quality α, in subregion r,

$W_{ip(r)}$ - consumption "on place" of crop i products by people related to producer type p, in subregion r,

$Z_{ip(r)}$ - consumption "on place" of crop i products by livestock within the producer type p economy, in subregion r,

$R_{ipl(r)}$ - sale of crop i products, by producers p, through market l, in subregion r,

$X_{jps'(r)}$ - number of livestock j, bred within the producer type economy p, with breeding technology s', in subregion r,

$Y_{jps'}(r)$ - absolute attrition number of livestock j, within the producer type economy p, with breeding technologys', in subregion r,

$T_{jpl}(r)$ - number of animals j sold alive, by the producer type p, through market l, in subregion r,

$V_{jpl}(r)$ - as for $T_{jpl(r)}$, animals bought alive,

$W_{mp}(r)$ - consumption "on place" of livestock product m, by people related to producer type economy p, in subregion r,

$Z_{mp}(r)$ - consumption "on place" of livestock product m, by livestock in producer type economy p, in subregion r,

$R_{mpl}(r)$ - sale of livestock product m, by producer type p, through market l, in subregion r,

$P_{ipl}(r)$ - purchase of crop product i, for feeding livestock in producer type economy p, market l, in subregion r,

$Q_{ipl}(r)$ - purchase of crop product i, for people related to producer type economy p, from market l, in subregion r,

$Q_{mpl}(r)$ - as for $Q_{ipl(r)}$, with livestock product m.

Coefficient table notations shall not be given here since they will take too much space and the contents of tables becomes evident from the model structure, shown in Appendix B.

Appendix B: Model formulation

I. Subregional level

I1. Available agricultural land:

$$\sum_{i \in I-I^p, s} X_{ips\alpha r} \leq L_{p\alpha r} \qquad \text{for all } p, \alpha, r$$

I2. Land limits for individual crop rotation groups:

$$\sum_{i \in I^w, s, \alpha} X_{ips\alpha r} \leq L^{max}_{wpr} \qquad \text{for all } p, w, r$$

I3. Land available for secondary crops:

$$\sum_{i' \in \beta_i \subset I^p, s, \alpha} X_{i'ps\alpha r} \leq \sum_{i \in \gamma_{i'} \subset I-I^p, s, \alpha} X_{ips\alpha r} \qquad \text{for all } \beta_i, \gamma_{i'}, p, r$$

I20. Crop production balance:

$$\sum_{s,\alpha} U^o_{ips\alpha r} \cdot X_{ips\alpha r} - W_{ipr} - Z_{ipr} - \sum_{l} R_{iplr} = 0$$

for all i, p, r

I30. Livestock slaughter products´ balance:

$$\sum_{j,s'} h^{M1}_{mjps'} \cdot Y_{jps'r} - \sum_{j,l} h^{M1}_{mjpl} T_{jpl} + \sum_{j,l} h^{M1}_{mjpl} V_{jpl} +$$

$$- W_{mpr} - Z_{mpr} - \sum_{l} R_{mplr} = 0$$

for all p, r, $m \in M1$

I31. Livestock continuous production balance:

$$\sum_{j,s'} h^{M2}_{mjps'} \; X_{jps'r} - \sum_{j,k,s'} h^{M21}_{mjps'} \; Y_{jps'r} +$$

$$- W_{mpr} - Z_{mpr} - \sum_{l} R_{mplr} = 0$$

for all p, r, $m \in M2$

I32. Livestock number balance:

$$N^{min}_{jpr} \leq \sum_{j',s'} g_{jj'} \; X_{j'ps'r} - \sum_{s'} Y_{jps'r} \leq N^{max}_{jpr}$$

for all j, p, r

I33, 34 Livestock feeding balance:

$$\sum_{j,s'} f^{min}_{nj} \; X_{jps'r} \leq \sum_{i} g_{in} \; Z_{ipr} + \sum_{i,l} g_{in} \; P_{iplr} +$$

$$+ \sum_{m} g_{mn} \; Z_{mpr} \leq \sum_{j,s'} f^{max}_{nj} \; X_{jps'r}$$

for all n, p, r

I40. Crop product consumption balance:

$$F^{min}_{ipr} \leq W_{ipr} + \sum_{l} Q_{iplr} \leq F^{max}_{ipr}$$ for all i,p,r

I41. Livestock product consumption balance:

$$F^{min}_{mpr} \leqslant W_{mpr} + \sum_{l} Q_{mplr} \leqslant F^{max}_{mpr} \qquad \text{for all } m, p, r$$

I50. Resource constraints: labor force:

$$\sum_{i,s,\alpha} b_{ips\alpha} \cdot X_{ips\alpha r} + \sum_{j,s'} b_{jps'} \cdot X_{jps'r} \leqslant B_{pr}$$

for all p, r

I60. Resource constraints: water, annual:

$$\sum_{i,s,\alpha} d_{ips\alpha r} \cdot X_{ips\alpha r} + \sum_{j,s'} d_{jps'} \cdot X_{jps'r} \leqslant D_{pr}$$

for all p, r

I61. Resource constraints: water, first peak

$$\sum_{i,s,\alpha} d^{1}_{ips\alpha r} \cdot X_{ips\alpha r} + \sum_{j,s'} d_{jps'} \; X_{jps'r} \leqslant D^{1}_{pr}$$

for all p, r

I62. Resource constraints: water, second peak:

$$\sum_{i,s,\alpha} d^{2}_{ips\alpha r} \cdot X_{ips\alpha r} + \sum_{j,s'} d_{jps'} \; X_{jps'r} \leqslant D^{2}_{pr}$$

for all p, r

I70. Resource constraints: pulling power:

$$\sum_{i,s,\alpha} e_{ips\alpha} X_{ips\alpha r} - \sum_{j,s'} e_{jps'} \cdot X_{jps'r} \leq E_{pr}$$

for all p, r

I71. Resource constraints: fertilizers:

$$M_{fpr} \leq \sum_{j,s,\alpha} a_{fips\alpha} X_{ips\alpha r} - \sum_{j,s'} a_{fjps'} X_{jps'r} \leq G_{fpr}$$

for all f, p, r

180÷83 Purchase balances: according to purposes:

$$\sum_{p,i \in \eta_{t1}} P_{1iplr} \leq H_{t1lr} \qquad \text{for all t1, l, r}$$

$$\sum_{p,i \in \eta_{t2}} Q_{2iplr} \leq P_{t2lr} \qquad \text{for all t2, l, r}$$

$$\sum_{p,m \in \eta_{t3}} Q_{3mplr} \leq P_{t3lr} \qquad \text{for all t3, l, r}$$

$$\sum_{p,j \in \eta_{t4}} V_{4jplr} \leq K_{t4lr} \qquad \text{for all t4, l, r}$$

I84, 85, 86: Sales balances according to kind:

$$\sum_{p,i\in\eta_{t1}} {}_1R_{iplr} \leqslant J_{t1lr} \qquad \text{for all } t1,\ l,\ r$$

$$\sum_{p,m\in\eta_{t3}} {}_3R_{mplr} \leqslant J_{t3lr} \qquad \text{for all } t3,\ l,\ r$$

$$\sum_{p,j\in\eta_{t4}} {}_4T_{jplr} \leqslant L_{t4r} \qquad \text{for all } t4,\ l,\ r$$

I90. Financial limitation: investment outlays:

$$\sum_{i,s,\alpha} c_{ips\alpha r}\ x_{ips\alpha r} + \sum_{j,s'} c_{jps'}\ x_{jps'r} \leqslant C_{pr}$$

for all p, r

I91. Financial balance: minimum net revenue:

$$\sum_{i,l} P_{il}\ R_{iplr} + \sum_{m,l} P_{ml}\ R_{mplr} + \sum_{j,l} P_{jl}\ T_{jplr} +$$

$$- \sum_{i,s,\alpha} s_{cips\alpha r}\ x_{ips\alpha r} - \sum_{j,s'} s_{cjps'}\ x_{jps'r} +$$

$$- \sum_{j,l} P^{imp}_{jl}\ V_{jplr} - \sum_{i,l} P^{imp}_{il}\ P_{iplr} - \sum_{i,l} \bar{P}^{imp}_{il}\ Q_{iplr} +$$

$$- \sum_{m,l} P^{imp}_{ml}\ Q_{mplr} \geqslant F_{pr} \qquad \text{for all } p,\ r$$

II. Regional level

II1. Resource constraints: labor force:

$$\sum_{p,r} B_{pr} \leqslant B$$

II2, 3, 4. Resource constraints: water

$$\sum_{r'} DDrr' \sum_{p} D_{pr}^{1,2} \leqslant DD_r^{1,2} \qquad \text{for all } r, \text{ annual and peak periods}$$

II5. Resource constraints: pulling power (energy):

$$\sum_{p,r} E_{pr} \leqslant E$$

II6. Resource constraints: fertilizers:

$$\sum_{p,r} G_{fpr} \leqslant G_f \qquad \text{for all } f$$

II7. Financial limitations:

$$\sum_{p,r} C_{pr} \leqslant C$$

III. Objective functions.

Objective functions for level I reflect production and trade balance features of the local system. The bàsic criterion for this level is a sum of slightly modified left hand sides of I91. The upper level criterion is founded upon the constraint efficiency data from level I in the vicinity of an anticipated RHS vector value.

MODELLING OF ALLOCATION IN AGRICULTURAL DEVELOPMENT PROGRAMMING

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1. Problem formulation

This paper shall deal with methodological problems of construction of a type of agricultural computer models. The models should account for division of a territory /a complex object/ into non-homogenous spatial units /basic objects/. This may reflect e.g. an administrative territorial breakdown. The overall model would then consist of a number of individual basic objects' descriptions. The individual descriptions should allow appropriate shaping of projections of future agricultural development and of allocation of tasks and benefits among basic units /"regions"/. It must be mphasized that non-homogeneity of basic units and their high number are assumed. Every basic unit (region) has soils differing in quality and other specific features /see Góralczyk J., 1980/. Diversity of agricultural conditions for e.g. the case of Poland is illustrated in Table 1. Furthermore, social and economic conditions of agriculture are spatially diversified as well /see Góralczyk, M., 1980/.

It is assumed that the model is meant to optimize the organization of agricultural activities, i.e. resource volumes used, plans and benefits. The model should generate an optimum for the overall complex object and for interregional allocation, and - to the extent possible - for individual regions. Interregional allocation should take into account incomes of farmers

Table 1: Agricultural habitats of Poland

	Agricultural land shares in %, in agroclimatic regions:					
	Total	A	B	C+D	C	D
Growth intensity and geographic location						
Total	100,0	79,5	17,1	3,4	3,1	0,3
intensive /A/	79,5	79,5	-	-	-	-
weakened:						
: in northern regions /B/	17,1	-	17,1	-	-	-
: in mountaineous regions /C/	3,1	-	-	3,1	3,1	-
strongly shortened:						
: mountains /D/	0,3	-	-	0,3	-	0,3
Agricultural land:	100,0	100,0	100.0	100,0	100,0	100,0
Arable land /total/: with soils:	79,6	80,3	78,6	67,8	71,1	27,7
good for root crops:						
dense	14,9	14,6	17,1	12,4	13,4	-
medium	15,1	16,3	12,1	0,3	0,3	-
light	15,6	16,5	14,6	-	-	-
loose	23,1	24,0	23,1	-	-	-
dense and medium eroded:						
strongly	3,4	2,8	3,0	19,5	21,1	-
weakly	2,0	0,9	1,4	31,0	31,3	27,7
heavy:	5,5	5,2	7,3	4,6	5,0	-
Permanent grassland, total:	20,4	19,7	21,4	32,2	28,9	72,3
meadows and pastures	20,2	19,7	21,4	27,6	28,9	12,4
sheep pastures	0,2	-	-	4,6	-	59,9

in individual regions. An interplay between local and global optima should be made explicit, and it would then mainly influence the shape of interregional specialisation and allocation.

In case of a mixed agricultural economy an analogous problem appears for allocation and specialisation among land-ownership types.

In works devoted to optimization of complex objects examples are found of LP formulations suggesting block structure of appropriate LP problems /Gajewski, 1971; Nietupski, 1969, 1979/. The number of blocks corresponds to number of basic units, hence technical computational limitations are introduced for cases with high number of basic units /Nietupski, 1976/. However, it seems necessary, because of analytical and other reasons, to construct and perceive of whole series of models for individual objects.

As for as works dealing with sensu stricto regionalization /regional specialization/ of agriculture in normative terms are concerned, an attempt for Polish conditions has been made a few years ago /Góralczyk, J., 1979 a/. This attempt consisted in determination of an optimal aggregate, composed of few various objects, internally homogenous, which can be treated as "elements" of features found in the whole variety of non-homogenous objects. This makes it very important to perform a detailed analysis of empirical data constituting the basis of "element" definition /Góralczyk, J., 1969/. The same applies to modelling of allocation.

2. Some remarks on the conventional farm activity optimization methods

Let us consider for a while optimization methods for a single basic object such as a farm or farming enterprise. This is justified insofar as allocative optimum is in fact a deployment of a simple choice optimum obtained for one object. On the other hand, a farm, in general, encompassing various types of agricultural land, such as meadows, pastures, dryland, wetland etc., with various soil conditions, may quite well represent the same sort of problem as seen in a spatial unit of a higher order, up to the whole of the country. The analogy is formal, but essential: in appropriate descriptions similar elements have to be represented. Thus, before passing over to higher order spatial units, methodological problems should be sorted out for farm programming. There is, however, still a lot of discussion on the applicability of LP techniques /Schmidt, 1958, 1971; Daw, 1964, Góralczyk, J., 1969/ in farm programming, while these techniques are already for some time taught in agricultural colleges and universities.

It should be noticed that agricultural LP problems usually take on a standard form in which the matrix of a_{ij} coefficients is composed of vectors constituting descriptions of individual agricultural activity directions, in particular - of production of individual crops. This sort of formulation implies that any product, described by given vector, is competitive with regards to other products, and that it may be used as a resource for their production as well /self-supply/. Thus, resource use and other limitations - usually arbitrary - constrain the optimum which tends to show relative competitiveness of various products, represented by vectors $a_{.j}$.

Illustrations of this sort of LP formulation for Polish conditions are biassed towards preference for rapeseed as a highly competitive crop. Other considerations, however, make it necessary to limit the share of surface under rapeseed. Hence, the conventional model does not account in an adequate way for essential features of the farming system, especially for the capacity and need of self-regulation. Adequacy, for this particular case, could be achieved by lowering of the competitive strength of the rapessed, representing the fact that too much of this crop may be risky from the point of view of yield, harvest losses, soil fatigue, worse crop-rotation conditions for following crops, as well as greatly increased labour intensity during harvest, i.e. an addtitional cost increase. However, all these factors are not considered, at least because of lack of emprical basis, and are not included in $a_{.j}$ Furthermore, a model relating features of an activity to its scale or share would be inhibitingly complex.

Another drawback of thus /vector - simple activity, see Góralczyk, 1969/ construed LP model consists in omittance of the possibility of improving the cost/output ratio within individual activities through restructuring, which does, in fact take place in farming reality. This is related to optimization of substitution rates in output-defining formulae. Hence, such models generate often large structural activity shifts, while yielding small economic gains.

Finally, let us notice that objects appearing in the conventional LP formulation represent real farming systems through quite "distant" abstractions. Thus, optimal solutions refer to nonexistent, e.g. new, farming system. This happens in spite of efforts to make local conditions appear accurately enough in the model. It is, namely, impossible to account precisely for all flows in such a system, for instance flows originating and ending within the farm, especially when they change their characteristcs over the process course.

The above remarks should be taken into consideration when setting up an agricultural LP model on the basis of empirical data.

2. An alternative to the conventional method

The shortcomings of the conventional method have made the present author to adopt another model, based upon descriptions of farms or enterprises, in terms of vectors $a_{.j}$, rather than upon descriptions of individual activities. In Poland there exists a source of reliable data of that form, namely the Institute of Farming Economics surveys constantly several thousand so called accounting farms. Subsets of farms from this sample show definite differences, so that it is possible to perform an analysis in which intra-farm-type relations will change depending upon inter-farm-type differences. A set of vectors $a_{.j}$, representing this time farm types, will constitute matrix $\{a_{ij}\}$ which, as in conventional method, can be treated as an LP problem matrix, and solved via usual techniques /Góralczyk, J., 1967/.

Model of a farm, based upon a subset of empirical farm descriptions, does not show these shortcomings which were cited before with regard to multi-activity or branch models.

Optimization, however, when based upon statistical data, has strictly limited value for normative, active planning and organizational purposes. Namely, an optimum obtained cannot transgress the area defined through coefficients constituting the matrix $\{a_{ij}\}$, i.e. reflecting the present state of things. This is not a problem when considering an improvement in average or weak farms. When, though, an essential development is aimed at through new production organization, identification of its capacities can be done via an extrapolation of capacity trends existing withih the sample considered, and construction of new, "artificial" objects. Such an approach was used in order to determine the possibilities of conjoint maximization of income of farmers, and of grain and feedstuffs surplus in farms with various resource conditions /Góralczyk, J., 1970/. This approach served also to elaborate the optimal profile of private farming over a larger region /Góralczyk, J., 1972/.

In additon, although the method advocated does not allow a broader scope of choice of organizational structures, it still can give an essential improvement in final economic output. This has been proven by an experiment in which over three years a farm chosen to change its profile towards the optimum had almost doubled its income. The income achieved was slightly lower than anticipated and than that obtained on the real farm taken as representing optimum /Góralczyk, 1972/. The optimization method based upon the synthetic farm descriptions gives, therefore, results comparable with those of marginal calculus meant for farm advising services in other countries /Daw, 1964; Gunia, 1979/. Furthermore, when comparing the optimal farm models with real-life farms, and among themselves, one can see that optimal programs propose an economy in which cost/output ratio is rather improved than worsened. There is, therefore, both a requirement, and an indication of direction, of an improvement in farming efficiency. The knowledge of ways of improving farming efficiency, as pointed out by de Wit, 1975, may be itself a condition for saving the agriculture from a decline in efficiency of labor and energy when increasing soil productivity.

3. A prototype allocation model

Previous results obtained with the method of synthetic farm representations have constituted an encouragement for an attempt of its application over the regions of the whole country. This attempt was meant to test the adequacy of types obtained from the sample gathered by the Institute of Farm Economics for active optimization of farming and agricultural organization.

The problem envisaged incorporated determination of an - optimal - model[*/] pattern of agricultural land utilization for homogenous territories with various environmental conditions. This model pattern was meant to show what structures of land utilization in particular homogenous areas allow maximization of crop productivity together with a compromise of production structure and resource use efficiency requirements. Thus, diversification of the optimized land utilization shall indicate roughly environmentally homogenous areas which should serve as sources of individual main crops. Hence, this allocative optimum for crop production may, in a planned economy, or an economy with important state intervention, serve as a basis for patterns of allocating specializations among administrative units representing relatively homogenous areas.

In analysing this problem a number of assumptions were formulated as to the substantive and formal questions related to the method of programming allocation of crop production /optimization of choice and share/:

1. Homogenous regions considered would correspond to the so called "soil-and-agricultural complexes" or "habitats" /see Table 1/. Such a homogenous region displays a net domination of a certain environmental habitat, and definite shares of arable land and grassland. The region may contain a variety of land—ownership types, if a mixed agricultural economy is considered[* *]

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*/ the word "model" is used here to denote an object which is best, and after which other objects should be shaped /ed./

* */ note a difference with the two-level model, where it is postulated that various producer types be accounted for separately /ed/.

2. In programming problem formulation the whole land utilization structure within a region was treated as an activity. Thus, crop yields may be made dependant upon their arable land share and rotation. Furthermore, not only areas under crops and their yields define their final efficiency of use, but also the sort of processes they undergo on the farm.
3. Activities are evaluated according to the criterion of total output from a unit area of arable land, expressed in grain equivalents or other physical units. Intermediate products are evaluated similarly to Scandinavian pasture utilisation measure. Hence, total of crop production is measured via a proxy of final net product, i.e. the effective product of land. Another criterion used was so-called grain surplus, i.e. the difference between grain volumes harvested and used up on the farm, including high-protein-content feedstuffs.
4. It was assumed that the source data for optimum choice and allocation programming will be uniquely empirical data, although such information meant explicitly for optimization of the overall land utilization /farming/ systems were not available until now. The procedure of data preparation, an essential task in itself, was as follows:
   - accounting farms of the Institute of Farm Economics were classified according to their administrative belonging and physiographic features of the area to form 102 subsets of the whole sample, then
   - homogenous regions were defined on the basis of soil and land utilization characteristics, 4 in number, to which altogether 41 subsets of farmes were assigned differing in land utilization and production process organization; differences of subsets /secondary objects/ - see Tables 2 and 3 - are partly related to land ownership differences, and partly to individual farmers' decisions.

The possibility of distinguishing relatively homogenous regions with clear diversity of land utilization within each of them determines the fundamental analytical information. All four regions are roughly characterized in Tables 2 and 3.

Optimization formally consists in definition of shares assigned to secondary objects /"farm types"/ within each region so as to maximize objective function /evaluation critaerion/ value and satisfy given constraining conditions. Thus, maximum of net final crop product per 1 hectare of arable land over all regions was sought, with requirement that an average of grain surplus for efficient farms, i.e. 0.28 t/hectare of arable land, be at least kept to throughout the system. Furthermore, land availability and grassland share constraints were imposed.

Some features of optimal solutions are shown in Table 3. In general these optimal solutions indicate a possibility of increasing the average crop production levels in all four regions by 18%, including an increase in production of cereals of 16% which would mean liquidation of the grain shortage. Such directions of changes were anticipated. This improvement of the production situation is parallelled by an improvement in incomes from farms, as represented through their subsets. Optimal solutions postulate a decrease of differences of land productivity among regions, together with an increase of differences in grain balance. This result, as well as the improved income, can be attributed to problem formulation, in which both activity choice and interregional production allocation are contained. Hence, optimization leads to assigning an additional burden of grain surplus production to those regions in which there is a small grassland share. The possibility of turning out adequate grain surpluses and of having high land productivity is additionally, obviously, related to agricultural habitat features, conditioning the freedom of choice of crops.

The latter dependence is well pronounced for soil characteristics, considered according to mechanical classification: dense, medium, light and loose. Specifies of medium soils in the second region in the optimum may be of interest. These soils often suffer of humidity shortage and they turn out to be mostly occupied by cereals and potatoes. Thus, sugar beets were eliminated from these areas, though theoreti-

Table 2: Farm subsets /"farm types"/ within particular homogenous regions

	Regions:							
	1		2		3		4	
Number of farm subsets:	11		9		11		10	
Intervals of features:	min	max	min	max	min	max	min	max
Land utilization, % of agricultural land:								
Totals:	96.5	100.2	97.8	100.1	97.2	100.4	95.5	100.0
orchards:	0.0	1.8	0.2	1.8	0.0	1.4	0.0	3.2
Cereals:	27.0	50.0	37.1	62.8	40.7	50.1	25.4	46.9
Wheat:	12.2	31.0	4.4	16.1	1.4	9.7	0.0	11.2
Rye:	0.0	18.1	3.4	26.2	21.3	33.2	7.8	24.8
Barley:	0.0	11.1	6.0	39.4	1.8	6.9	0.8	11.1
other:	2.7	15.5	4.1	13.6	3.3	15.1	3.7	14.7
Industrical: total	0.0	8.4	0.0	3.5	0.0	3.6	0.0	1.9
Rapeseed	0.0	5.7	0.0	2.8	0.0	3.0	0.0	1.0
Root crops:	16.7	44.1	22.8	44.0	19.4	34.6	13.9	33.2
Potatoes:	9.5	24.3	14.1	26.3	14.7	27.9	7.1	29.5
Sugar beets	2.2	11.1	0.0	10.6	0.0	5.8	0.0	1.8
Forage root crops:	0.8	5.5	1.1	5.4	0.0	4.2	1.0	3.2
Vegetables:	0.4	3.9	0.9	3.4	0.7	5.1	0.5	4.4
other:	0.0	3.9	0.0	3.8	0.0	1.0	0.0	0.2
Forage crops:	16.2	28.9	4.0	26.3	19.7	34.8	30.8	56.8
Field crops:	6.1	13.0	4.0	15.2	1.2	19.3	1.2	9.8
Grassland:	4.5	22.3	0.0	19.7	7.2	28.3	17.1	53.9
Secondary crops:	0.7	12.4	0.0	22.7	6.2	31.3	0.0	9.5
Output in grain units per hectare of ogricultural land:								
Total:	31.1	70.2	34.0	70.3	26.5	55.5	21.9	46.4
Cereals:	8.7	15.6	10.9	18.6	3.1	15.1	5.5	11.6
Potatoes:	4.9	13.2	7.5	16.9	6.6	15.4	3.0	15.5
other:	7.0	28.2	3.5	28.4	5.8	18.8	4.6	20.1
Grain surplus:	-4.1	6.7	-4.2	4.3	-9.5	2.1	-27.4	3.0

Table 3. Observed (a) and optimal (b) shares of crops in various regions

	Regions									
	1		2		3		4		Average	
	a	b	a	b	a	b	a	b	a	b
Land utilization in % agricultural land	99,0	100,0	99,2	100,0	99,3	100,0	98,8	100,0	99,1	100,0
Orchards:	0,7	0,4	1,1	1,8	0,8	0,3	1,0	0,4	0,9	0,7
Cereals:	43,3	45,6	48,9	49,0	44,2	48,7	37,8	34,0	43,6	44,3
Wheat:	21,8	28,5	9,3	9,8	4,8	8,8	6,0	7,1	10,5	13,5
Rye:	7,0	3,2	17,4	17,3	26,5	16,8	16,9	9,8	17,0	14,3
Barley:	4,6	5,6	13,8	12,6	4,0	4,6	3,9	2,2	6,6	6,3
other:	9,9	8,3	8,4	9,3	8,9	8,5	11,0	14,9	9,5	10,2
Industrial crops, total:	3,2	5,0	1,2	4,0	1,6	2,1	0,9	-	1,7	2,8
Rapeseed:	2,1	2,7	0,9	4,0	0,9	1,2	0,2	-	1,0	2,0
Root crops:	27,6	24,4	29,0	26,7	26,6	28,0	20,8	25,1	26,0	26,1
Potatoes:	15,7	11,7	19,3	22,0	20,4	18,9	16,3	18,3	17,9	17,7
Sugar Beets:	7,2	8,4	4,4	-	2,6	5,4	0,8	1,8	3,8	3,6
Forage root crops:	2,5	2,2	2,5	2,0	1,6	1,8	1,9	3,2	2,1	2,3
Vegetables:	1,7	1,4	2,2	2,1	1,9	1,9	1,8	1,8	1,9	1,8
other:	0,5	0,7	0,6	0,6	0,1	-	-	-	0,3	0,3
Forage crops:	24,2	24,6	19,0	18,5	26,1	20,9	38,3	40,5	26,9	26,1
Field:	9,7	8,5	9,8	9,3	9,9	4,7	5,9	4,9	8,8	6,9
Grassland:	14,5	16,1	9,2	9,2	16,2	16,2	32,4	35,6	18,1	19,2
Secondary crops:	6,9	4,1	9,4	6,4	16,2	16,6	4,2	5,8	9,2	8,2
Output, in grain units per hectare of agricultural land,										
total /max/	44,1	45,7	44,7	53,0	37,2	45,5	30,9	40,8	39,2	46,3
Cereals:	12,9	14,8	13,9	16,0	10,5	14,2	9,1	9,0	11,6	13,5
Potatoes:	7,9	6,1	10,3	14,4	10,1	10,1	8,0	9,4	9,1	10,0
Sugar beets:	6,6	8,3	4,2	-	2,2	5,0	0,8	1,8	3,4	3,8
other:	16,7	16,5	16,3	22,6	14,4	16,2	13,0	20,6	15,1	19,0
Grain surplus:	1,9	5,1	0,5	5,4	-0,9	2,9	-3,1	-2,1	-1,6	2,8

cally they can occupy there a share not smaller than on the dense soils of the first region, and contribute to the overall crop production level increase. In other regions, however, sugar beets play a more important role.

The interregional production allocation scheme indicates a shift in root crops production towards light soils, field-and-meadow areas included. This shift is a reflection of the productivity increasing and feedstuff supply roles of root crops, especially important there, where land productivity is low, as indicated by narrow choice possibilities and low grain yields. In addition, a change in root crop structure may be important, for instance an increase in sugar beet share, since this crop provides the highest yields of useful plant volume, even on light soils. These soils can also be used for forage root crops and vegetables.

A sharp selection of synthetic activities considered leads in the optima to distinct differences in land utilization between regions, as it is observed in reality.

It is possible to formulate such an optimization problem, i.e. an objective function /evaluation criterion/ and a set of constraining conditions that would account for competing goals of agricultural activity. This formulation might give insights into ways of making the production allocation mechanism a tool in an effective development of agriculture, especially in areas with low productive potential.

4. Data preparation problem

In the optimization task commented previously upon data were used from the accounting farms, grouped into subsets of several to several dozens, through their averages. Each description obtained represented farms of similar area, but having various habitat conditions /see Table 1/. Objects having similar habitat conditions had to be picked out very carefully, and only four blocks of descriptions for regions with full growing season could be formed. Thus, although a rich data source, such as the sample of the Institute of Farm Economics, was taken, a large portion of potentially useful information therein was lost, because it was not meant for this sort of use. Adequacy of data is of no less value than its accuracy. This regards, for instance, the correspondence between spatial units for which data are defined, often of administrative nature, and the areas of homogenous agricultural features /see Dettwiler, 1981/.

When determining data requirements for a modelling project, which is to aid planning and policy making, one should take into account the fact that these are on-going, continuous processes, in which various problems arise over time. Thus, it must be anticipated that data requirements may also change. These changes may be related to a need of extrapolation /creation of new synthetic farming systems/, especially when some parameters of farming system reach their extremal values, or transgress the intervals span up to date. This may regard shifts in production directions, in outlays, in potentialities of the genetic material, or in income level expectations.

In order to be able to generate such information one must treat the data available as a statistical series subject to multivariate analysis, with the aim of prediction. The possibility of using such procedures for predicting whole structures was shown by Góralczyk, J., 1979 b, 1981, with values of structure parameters far outside the intervals observed.

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OPTIMAL ORGANISATION OF THE FOOD SUPPLY ZONE OF AN AGGLOMERATION:
the case of Szczecin agglomeration in Poland

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1. Introduction

The food supplying zone of an agglomeration is the area of the adjacent agricultural land, whose outputs are destined for satisfying the agglomeration population's needs in food products to be consumed fresh, which are sensitive to long distance transportation.

In the particular case here considered the aim of the study was to determine the optimal agricultural production structure for the food supplying zone of a particular agglomeration, i.e. Szczecin area in the north-western Poland.

Special attention was paid to milk production organisation and scale. This problem deserves special attention because milk is a highly sensitive product itself, and there exists a need of

- decreasing the overall social costs of milk production, transportation and processing, and within this requirement:
  - shortening the delivery time and decreasing volume and quality losses.

The study was carried out in two segments, founded on different approaches.

2. Transportation cost decrease study

The food supplying zone was divided into 3 subzones according to distance /subzones I, II and III/. The transportation cost reduction was calculated for varying assumptions as to changes in milk transfers into agglomeration from the three subzones. The changes considered consist in decreasing of transfers from farther-off subzones and appropriate increases in transfers from closer-in subzones. The alternatives considered were as follows:

A.	: inner subzones are I and II; : outer subzones are III and other provinces;	A1. transfers from inner subzones increased by 20%, and from outer subzones decreased by 25%, A2. transfers from inner zones increased by 40%, and from outer subzones decreased by 50%, A3. transfers from inner zones increased by 60%, and from outer subzones decreased by 75%.
B1	: inner subzone: only I; : outer subzones are II, III and other provinces;	B1.1. transfers from the inner subzone increased by 25%, B1.2. transfers from the inner subzone increased by 50%, B1.3. transfers from the inner subzone increased by 75%, B1.4. transfers from the inner subzone increased by 100%, with appropriate decreases in transfers from outer zones.

B2. : as B1., with essential decrease in seasonal variation of volumes of supply /change of technology/.

Resulting changes in the overall transportation costs were estimated according to the approximated formula:

$$\Delta C_T = C^{out} (K_1 - K_2) - C^{in} (k_1 - k_2)$$

where C_T is the total cost differential, C^{out} is the overage cost coefficient for outer subzones, K_1 and K_2 are transfers from outer zones, C^{in} is the average cost coefficient for inner subzones, and k_1 and k_2 are again transfers, this time from inner zones.

Calculation results are shown in Table 1.

Alternatives:		Cost decreases expressed in % of:	
		present milk transportation costs	present total milk supply cost
A	1	6,91	2,81
	2	13,01	5,28
	3	18,67	7,58
B_1	1	5,57	2,26
	2	10,96	4,45
	3	15,72	6,38
	4	19,54	7,94
B_2	1	28,42	11,54
	2	34,02	13,82
	3	37,90	15,39
	4	40,08	16,28

Table 1. Cost decreases owing to changes in the milk supply pattern over the supplying zone of Szczecin agglomeration.

In terms of the milk price the decreases achieved with alternatives B2 amount to about 3.5%.

The results obtained point out the cost decrease capacities of the different spatial organisations of the milk supply zone, and also give some hints as to the way of realising additional economies, i.e. formation of large specialised milk farms less sensitive to seasonal variations.

3. Optimisation of the agricultural production structure within the supplying zone

In further studies it was assumed that the suburban /inner/ zone of this particular agglomeration was to be supplied with 80 - 90 $\cdot 10^3$ t of milk per year, according to population's needs. With such an assumption optimisation of the structure and scale of production in the state farming enterprieses and in the specialised private farms located in this zone was performed. A ring of up to 40 km in radius was considered, with 205 $\cdot 10^3$ hectares of agricultural land, but only 20 milk cows per 100 hectares. Such a low intensity of milk-production-oriented breeding resulted in the fact that in 1974 this zone supplied a mere 50% of milk processed in the municipal milk processing plant in Szczecin, while the other half had to be transported from farther zones.

In addition to milk supply requirements the demand for other milk - based products was determined to serve as an assumption in the study of optimal agricultural production organisation /cream: 7-9 $\cdot 10^3$ t per year, cheese and butter: 4.5-5.5 $\cdot 10^3$ t per year, condensed products: 1.1-1.8$\cdot 10^3$ t per year/. Together with milk, also vegetable supply /70-100$\cdot 10^3$ t per year/ was taken as a demand assumption.

The above number indicate the necessity of increasing milk production in the state farming enterprises located in agglomeration's inner zone by 260-400%, depending upon the degree of structural changes.

LP technique was used with the program coefficient matrix composed of 5 blocks and a group of common constraints /see Fig. 1/. Of the 5 blocks, 4 represent indi idual large state farming enterprises and the fifth one is an aggregate representing specialised private farmers in the inner zone.

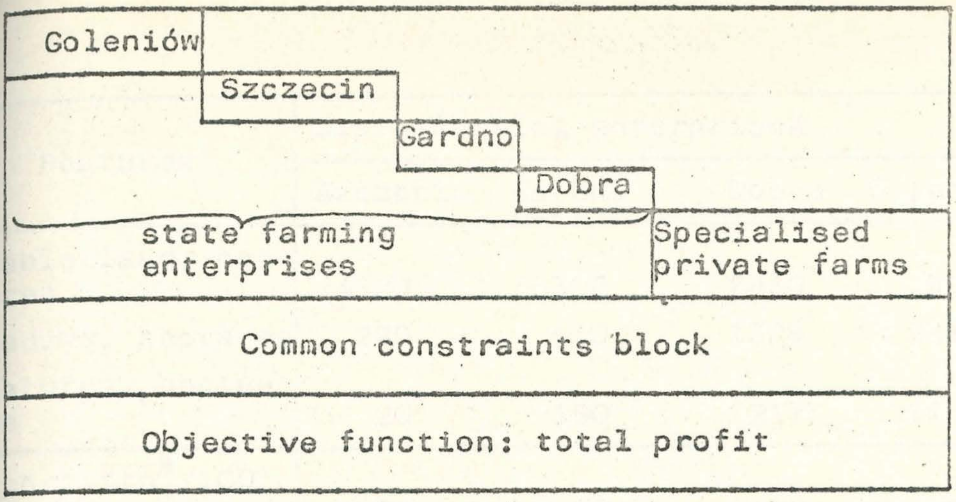

Fig. 1. Organisation of the linear programming coefficient matrix for the problem of agricultural production structure in the supplying zone.

Within the individual blocks particular activities related to field crop production, vegetable growing and livestock breeding are described. Common constraints block contains, inter alia, balances related to milk fows and cattle breeding. In the individual blocks cattle breeding is connected with other activities through land available, labor resoures and feed element balances /see Fig.2/.

Some characteristies of the objects represented by individual blocks in the LP matrix are given in Table 2.

In the private farms aggregate those farms which do not specialise in milk production were not accounted for because of their low share in the overall production volume. Pig raising and poultry was entirely omitted. In crop raising certain aggregation was performed and such groups as: cereals, early vegetables, late vegatables, pulse crops were treated as single activities, their internal structure predefined and constant.

The LP model, according to the goal of this study, emphasized the feedstuff balances and cattle raising, the latter through an approximate open herd structure dynamics. Minimal cow number was determined on the basis of existing or planned cow-shed capaciteis. Milk yield from cows was assumed to be 4.5 tons per year, and calfs past vealer stage were assumed to grow 1000 grams per day. Self-sufficiency of the state farming enterprises and private farms in terms of volume feedstuffs

Features	State farming enterprises				Specialised private farms
	Szczecin	Gardno	Dobra	Goleniów	
Arable land, hectares	4320	6300	2430	900	1500
Meadows, hectares	220	630	1328	5360	50
Pastures, hectares	20	150	217	1100	-
Labor, fte*/100 hectares	12	10	10	10	18
Crop yields, average, tons per hectare					
Cereals	4,1	4,1	3,1	3,1	4,1
Vegetables	35,0	-	-	-	-
Potatoes	20,0	20,0	18,0	18,0	30,0
Rapeseed	3,0	3,0	2,0	2,0	3,0
Forage crops**	50,0	50,0	35,0	35,0	50,0
Maize**	70,0	70,0	50,0	50,0	70,0
Meadows **	30,0	45,0	45,0	45,0	45,0

Table 2. Characteristics of agricultural producers in the inner zone of the Szczecin agglomeration.

*fte: full-time-employed equivalent

**: expressed in green mass

was assumed, together with purchase of protein foods. Coefficients of the LP matrix were determined on the basis of analyses of more accurate models of individual types of objects, taking into consideration opinions of enterprise managing staff and agricultural technological forecasts. Advanced technologies of crop production and large-scale cattle breeding technology were assumed. Costs were calculated for price level of 1975.

Some data appearing in Fig 2 were presented in Table 2.

Table 3 presents roughly the production structure and specialisation pattern obtained as the result of optimisation.

Features	State farming enterprises				Private farms	Total
	Szczecin	Gardno	Dobra	Goleniów		
Utilized land, in hectares	4320	6200	2300	900	500	15320
Cereals/%/	25,0	28,7	35,2	36,0	40,0	30,2
Potatoes /%/	6,7	4,8	15,2	-	8,8	7,0
Sugar beets /%/	3,5	7,8	5,6	-	9,7	6,1
Vegetables /%/	30,1	-	-	-	-	8,5
Rapeseed /%/	-	7,9	5,2	-	7,7	4,8
Forage crops /%/	34,7	47,6	37,8	64,0	33,8	42,1
Total net production value, in 10^6 zlotys	227	234	113	238	85	997
Crop production /%/	56	35	25	22	29	35
Vegetables /%/	39	-	-	-	-	10
Dried forage /%/	-	-	-	21	-	5
Cattle raising /%/	44	65	75	78	71	65
within which: milk /%/	40	46	39	29	63	41

Table 3. An outline of production structure and specialisation as resulting from the LP optimisation, for state farming enterprises and specialised private farms in the inner zone of Szczecin agglomeration.

The most pronounced features of the optimal specialisation pattern proposed are: full milk-production orientation of cattle breeding in the closest enterprise and in private farms, and location of the total of vegetable growing in the same enterprise.

The specialisation and intensity pictures are combined in Fig. 3, in which net product values per hectare of agricultural land are shown as attributable to various activities. Again, two "producers" come to the forefront, but, in general, diversification of production intensities expressed in monetary terms is admissible, for an LP problem optimising a global objective.

4. Concluding remarks

As mentioned above, the study shows that requirement of proximity in location of milk production does not necessarily entail large shifts in production structures, although an internal diversification of specialisations may occur. Hence, assuming appropriately favourable inter-producer exchange conditions one can await a resilient functioning of the proposed production organisation.

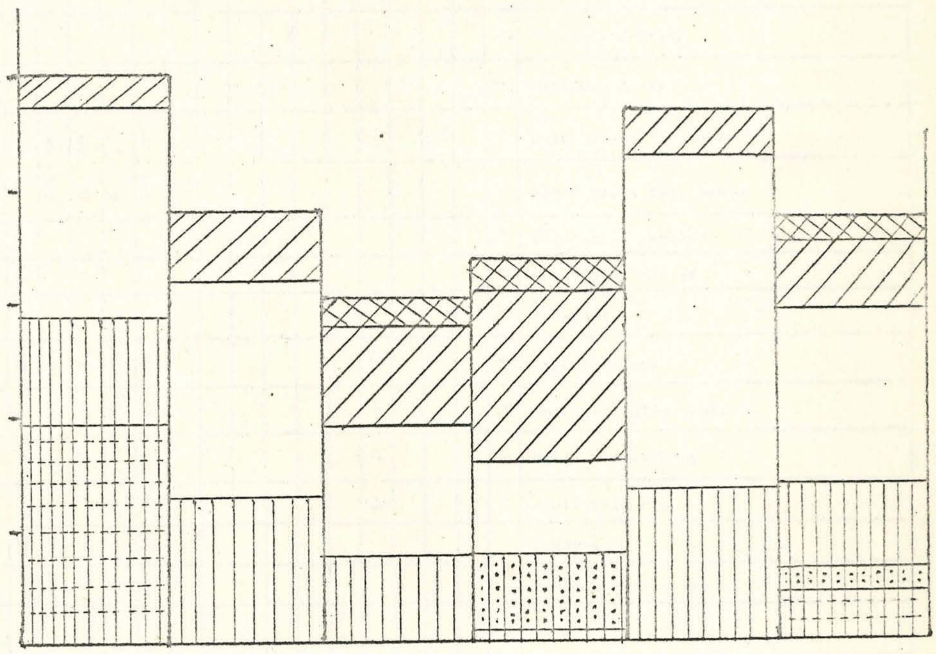

Fig.3. Net saleable production value per hectare of agricultural land associated with various activities

	Cereals	Pulse crops for grain	Potatoes /early/	Potatoes /late/	Sugar beets for sugar	Sugar beets for forage	Vegetables /early/	Vegetables /late/	Rapeseed	Papilionaceae	One-year pulse crops	Maize + aftercrop	Field pastures	Meadows	Permanent pastures	Cows	Female calfs /2 weeks/ sale	Female calfs /2 weeks/ purchase	Heifers /0-18 months/	Heifers /18-27 months/	Heifers /27 months/ for fertilization	Heifers /27 months/ purchase	Heifers /27 months/ sale	Bull-calfs /2 weeks/ sale	Bull-calfs /2 weeks/ purchase	Bull-calfs /2 weeks/ total	Bulls /0-18 months/	Sheep	Protein food: purchase	Milk for feeding	Type of constraint	Right hand sides	Measurement units
Arable land	1	1	1	1	1	1	1	1	1	1	1	1	1																		=	4320	ha
Meadows														1																	≤	220	ha
Cereals																															≥	1030	ha
Rapeseed									1																						≤	432	ha
Maize										-1	-1	-1	-1																		≤	0	ha
Female calfs /2 weeks/																0.45	-1	1	-1												=	0	1
Heifers /18 months/																			0.9	-1											=	0	1
Heifers /27 months/																				0.95	-1		-1								=	0	1
Heifers for fertilization																-0.2					1	1									=	0	1
Bull - calfs /2 weeks/																0.45								-1	1	-1					=	0	1
Bulls /18 months/																										0.9	-1				=	0	1
Oat units*					34	161				76	75	160	50	60	40	-4.5			-34	-20.7							-35.6	-3.8	9		≥	0	0.1 t
Proteins					3.7	7				15.4	7.4	9.8	4.7	6.5	4	-3.9			-3.6	-2							-3.5	-0.34	1.5		≥	0	0.1 t
Dry mass					46	173				96	100	161	60	62	44	-44			-34	-20							-34	-4.3	9		≥	0	0.1 t
Dry mass					46	173				96	100	161	60	62	44	-64			-44	-28							-44	-5.3	9		≤	0	0.1 t
Labor III rd period			1	1	44.8	44.8	28	53		12	12			10		6.5			3.5	0.9							3.5	2.2			≤	130000	manh.
Labor IV th period	13.9	26.4	50.3	2.3	2.6	2.6	243	3	7.8	12	12			10		4.2			2.2	0.6							2.2	1.4			≤	125000	manh.
Labor V th period	5	2,1		56,3	64	64	3.1	50	10	6.7	7.7	31,3		4		9.4			5	1.4							5	3.5			≤	178600	manh.
Protein food																1.2			1	0.3							1.35	0.15	1		=	0	t
Sheep																												1			≥	1200	1
Milk for feeding																			0.3								0.2			-1	=	0	t
Permanent pastures															1																≤	20	ha
Objective function: profit	9.6	18.3	47,1	2.8	36	-25.7	50	47	27.2	-4.5	-5.8	-9.2	-4	-4.2	-3	15.75	1	-1.1	-3	-1.5	0	-24	24	1	-11	0	11.7	0.8	-3.3	-45	→	MAX	

Fig. 2. Contents of the LP matrix block describing one of the state farming enterprises /block no. II, the Szczecin enterprise/

* oat units: units used in Poland for approximate evaluation of forage utility and value.

ECONOMETRIC MODEL OF ACTIVITY AS A DIAGNOSTIC TOOL FOR ANALYSING AGRICULTURAL ENTERPRISES OF A REGION

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1. Introductory remarks

An enterprise is an economic unit which, acting in a broader organisational, social, economic and legal setting, functions so as to achieve certain objectives related to production output, and in its functioning uses resources which are at its disposal. Hence, an enterprise should attempt to rationalise the use of these resources, while securing achievement of objectives.

In accordance with the above, diagnostic analysis of functioning of an enterprise should comprise accounting of inputs used and of output produced, and an evaluation of the manner in which the inputs were used, i.e. analysis of efficiency. Of special interest are here short-term analyses, so that constancy of enterprise structures can be assumed.

In order to perform such analysis it might be advantageous to treat enterprise as a cybernetic system. Functioning of an enterprise could then be described through reactions of outputs to stimuli appearing as inputs. Hence, efficiency analysis could be based upon regularities in these reactions, and correspondence of these regularities to certain norms or behaviour principles.

Technical possibilities of performing the analysis can be created only through functioning of a computer-based information system within the enterprise. This system would register the states of definite inputs and outputs, and would contain adequate methods and yardsticks for evaluating the quality of output reactions to input stimuli.

2. Methods of diagnostic analysis

Efficiency analysis may consist in simple registration of the input and output states, formation of synthetic indicators therefrom, and comparison of these indicators with predefined norms, averages etc. Thus conceived analysis can yield, however, doubtful results, since specificity of conditions in which individual enterprises act is overlooked. A more precise analysis would require definition of the enterprise - specific reaction functions. This would enable performing of rational comparisons of efficiency.

Input and output magnitudes of an enterprise are values of certain economic categories. These values can be estimated with the help of formalized econometric models. These models would then play a role of model enterprise transfer function.

Let $y_1,\ldots,y_r$ be variables describing states of observed outputs. Their values will be determined endogenously in the model. Values of variables $x_1\ldots,x_k$, describing monitored inputs, will be given exogenously. Delayed stimuli, as well as internal states distinct from inputs and outputs shall be omitted in the model. Hence, functioning of the enterprise can be described with the following mathematical model:

$$
\begin{aligned}
y_1 &= f_1\,(y_2,y_3,\ldots,y_r,\ x_1,x_2,\ldots,x_k) + \varepsilon_1 \\
y_2 &= f_2\,(y_1,y_3,\ldots,y_r,\ x_1,x_2,\ldots,x_k) + \varepsilon_2 \\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
y_r &= f_r\,(y_1,y_2,\ldots,y_{r-1},\ x_1,x_2,\ldots,x_k) + \varepsilon_r
\end{aligned}
\qquad /1/
$$

The random factor $\varepsilon = (\varepsilon_1, \ldots, \varepsilon_r)$ accounts for all the influences not considered explicitly in the model, in particular - for stimuli appearing on non-monitored inputs. Functions $f_{1,\ldots,r}$ depend upon some numerical constants, so called structural parameters. These constants can be identified theoretically, so as to obtain a yardstick model of enterprise, or they can be identified on the basis of observations of a group of enterprises /e.g. in a sector/, yielding an "average" enterprise model.

Efficiency analysis shall then consist in comparison of results of a given enterprise with either yardstick or average enterprise. The average enterprise parameters are usually determined via the least syuares methods. Application of these methods is straightforward when model /1/ is linear, i.e. of the form:

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_r \end{bmatrix} = \begin{bmatrix} 0 & \alpha_{12} & \cdots & \alpha_{1r} \\ \alpha_{21} & 0 & \cdots & \alpha_{2r} \\ \vdots & & & \vdots \\ \alpha_{r1} & \alpha_{r2} & \cdots & 0 \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_r \end{bmatrix} + \begin{bmatrix} \beta_{11} & \beta_{12} & \cdots & \beta_{1k} \\ \beta_{21} & \beta_{22} & \cdots & \beta_{2k} \\ \vdots & & & \vdots \\ \beta_{r1} & \beta_{r2} & \cdots & \beta_{rk} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_k \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_r \end{bmatrix} \qquad /2a/$$

or, shortly,

$$y = Ay + Bx + \varepsilon \qquad /2/$$

Matrices A and B can be interpreted in a simple way. Elements α_{ik} of A represent output interdependences, while elements β_{ik} of B represent input/output interdependences.

Formula /2/ can be transformed into

$$y = Cx + U$$

by putting $C = (I - A^{-1})B$ and $U = (I - A^{-1})\varepsilon$, where I is identity matrix. In /3/ every output is described with a separate equation.

It is, in general, quite difficult to obtain a model of enterprise in either form /1/ or /2/. In the present paper certain aspects of agricultural enterprise model construction shall be discussed. The models thus constructed can be used for diagnostic and for other, e.g. optimisation purposes, or, through a cybernetic interpretation, may constitute a basis for studies on the enterprise feedback control.

3. Principles of choice of variables

Determination of variables to be used in a model is an essential stage of analysis. Endogenous variables y measure economic effects of the enterprise and their choice depends upon the nature of the study, and upon the empirical material at hand. The choice of explanatory variables x must be particularly careful, since these variables must satisfy a number of conditions, namely:

- they must represent actual causes of changes in values of output efficiency criteria, and there should exist a way for assessing quantitatively the magnitudes of influence of each variable,
- for economic diagnostic applications the explanatory variables should account for all the essential objectively influencing factors, so that comparability between enterprises is achieved with precision up to non-considered subjective factors,
- in case comparison is made with an average enterprise, the latter must be representative for a whole considered enterprise population over a territory and a period of time, which requires appropriate statistical estimates.

Assume that model is formulated in the reduced form /3/. One can then consider just one endogenous variable, a criterion, i.e.

$$y = f(x_1, \ldots, x_k) + \varepsilon \qquad /4/$$

In order to construct an average enterprise model it is assumed that endogenous variable values $y_1, \ldots, y_n$ observed in individual enterprises are realisations of random variables $Y_1, \ldots, Y_n$, forming a random vector Y. It may, and often is, assumed that explanatory variables are not random, and their values, forming matrix X ,

$$X = \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1k} \\ x_{21} & x_{22} & \ldots & x_{2k} \\ \ldots & & & \ldots \\ x_{n1} & x_{n2} & \ldots & x_{nk} \end{bmatrix} \qquad /5/$$

were determinad before performing the statistical analysis. Since the model is in the /3/ form, y is expressed as

$$y = a_1 x_1 + \ldots + a_k x_k + \varepsilon \qquad /6/$$

where a_i $(i=1,\ldots,k)$ are unknown parameters and $x_k = 1$, so that a_k is a free element. Properties of parameter estimators are not worsened when values of explanatory variables, being realizations of random variables, satisfy the following conditions:

1. Matrix has maximal column rank
2. Conditional average $E(Y|X)$ is a linear function of X, i.e. it equals Xa, where a is a column vector of parameters $a_1, \ldots, a_k$.
3. Conditional covariance matrix of random vector Y is a scalar matrix, that is, $V(Y|X^*) = \sigma^2 \mathbb{1}$, $0 < \sigma^2 < \infty$, where σ is an unknown parameter and $\mathbb{1}$ is a unit matrix of appropriate order.

With these assumptions, ε has the following properties as a random variable:

$$\varepsilon = Y - X\ a, \quad E(\varepsilon|X) = 0\ , \quad V(\varepsilon|X) = \sigma^2 \mathbb{1}$$

Hence, the random elements ε_i are uncorrelated.

Assumptions 1. - 3. are general enough to be usually satisfied with independent sampling, especially when empirical data are of cross-sectional character. However, when these data are taken from the time series and there are pronounced linear trends then the assumption 1 on lack of colinearity of column vectors of X may not be satisfied. Assumptions 2 and 3 can be checked with known statistical tests.

In order to evaluate the degree of fitting of the model to reality the value of estimat s of variance in random component, corresponding to realisation y of vector Y is calculated, accompanied by:

a. estimation of standard errors of structural parameters, $s\, d_{ii}$, where d_{ii} are diagonal elements of matrix $(X'X)^{-1}$,

b. calculation of coincidence coefficient φ^2 and random variability coefficient $V_s = \frac{s}{\bar{y}}$.

Conditions specified before require adequate fitting of the model, i.e. low values of φ^2 and V_s, less importance is, on the other hand attached to essentiality of structural parameters estimation.

It should be emphasized that adequate choice of explanatory variables with regard to the explained, endogenous one, is a precondition for effectiveness of the whole efficiency evaluation procedure.

4. Econometric evaluation of efficiency

Let $b = (X'X)^{-1} X Y$ be the estimate of vector a of parameters, resulting from application of the least squares (LS) methods, and b^* - realisation of b corresponding to realisation y of Y. Ex definitio $Y = X a$, and $y^* = X b^*$ is the value of the endogenous variable vector obtained form the model. When efficiency is measured against the average of enterprises, the criterion value for i-th enterprise is $\tilde{Y}_i - y_i$. Since

$\tilde{Y}_i = \sum_{j=1}^{n} x_{ij} a_j$ cannot be observed, its estimate,

$y_i^* = \sum_{j=1}^{n} x_{ij} b_j^*$ is used. The actual difference $y_i^* - y_i$

may depend not only upon actual enterprise's efficiency, but also upon random factors. Following statistic is formed:

$$\frac{Y_i - y_i^*}{s} = \frac{Y_i - y_i^*}{\sigma} / \frac{s}{\sigma} = \frac{Y_i - y_i^*}{\sigma} / \sqrt{\frac{z^2}{n-k}}$$

where $z^2 = \frac{s^2(n-k)}{2}$

With this statistic it is possible to verify the hypothesis $H_o: \overline{Y}_i = y_i^*$ against $H_1: \overline{Y}_i \neq y_i^*$. It is assumed that vector Y has normal distribution with expected value Xa and covariance matrix $\sigma^2 \mathbb{1}$, and H_o. Numerator $\frac{Y_i - y_i^*}{\sigma}$ has then $N(0,1)$ distribution, while z^2 is distributed according to χ^2 with n-k degrees of freedom. Statistic considered has Student distrubution with the same, n-k, number of degrees of freedom. This distribution does not depend upon a and b, hence

$$P\left(\frac{|Y_i - y_i^*|}{s} \geqslant t_{n-k,\alpha}\right) = \alpha$$

with $t_{n-k,\alpha}$ contained in Student distribution tables. H_o hypothesis has then to be rejected at the α level when

$$\frac{|y_i - y_i^*|}{s} \geqslant t_{n-k,\alpha}$$

Thus, according to values of the difference $y_i - y_i^*$ the enterprises analysed can be classified into:

- really efficient, when: $y_i - y_i^* \geqslant s\, t_{n-k,\alpha}$
- efficient, when : $0 \leqslant y_i - y_i^* < s\, t_{n-k,\alpha}$

- inefficient, when : $-s\ t_{n-k,\alpha} \leqslant y_i - y_i^{*} < 0$

- really inefficient, when: $y_i - y_i^{*} < -s\ t_{n-k,\alpha}$

In case of the negative criterion the above inequalities are reversed.

5. Practical implementation

The methodology here discussed was implemented in the currently functioning management information systems in the state farming enterprises. These systems encompassed crop production (through field bookkeeping), milk-cow economices and meat production, and were implemented in enterprises of two provinces of Poland. Implementation was carried out with Polish minicomputers Mera 300 equipped with disc memories.

Systems were complemented with additional software for

- custom-made information generation,
- specialized print-out editing, and
- performing of economic efficiency analyses.

First of the above software functions is realised through a versatile common data base software. Customer can point out data units (records, record types) and basic operations to be performed on them (addition, averaging etc.) . Results are automatically edited and printed.

Specialised print-outs are predefined and cover a wide range of standard microeconomic analyses, related e.g. to production costs. Customer can combine them and/or specify objects over which such analyses are to be performed.

Economic efficiency analysis software can handle up to 12 thousand item samples, each item consisting of 21 variables. Each variable can be endogenous. Customer can choose endogenous and explanatory variables as well as the number of samples. Hence, various (up to 21) models can be created out of the variables specified by the customer. The software package peforming this function generates the following print-outs:

- source data, sample names, structural parameter values together with their averages,
- analysis of variability of source data together with their standard deviations and variability coefficients,
- efficiency analysis with classification of efficiency levels,
- conclusions from the analysis of regression coefficients and other statistical parameters, for instance - the multiple correlation coefficient.

The software systems created provide a clear overview and processing of data, acceptable for an average customer of computing equipment. The systems implemented are multipliable, i.e. they can be implemented in any organisational setting of agricultural enterprises.