REGIONAL AGRICULTURAL POLICY DESIGN ON THE BASIS OF A DETAILED LINEAR ECONOMIC AND AGROTECHNICAL MODEL

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PREFACE

The work in the Regional Development Task is oriented at problems of development of regions and systems of regions. Understanding of localized social and economic micro-processes should lead to achievement of capacity of development planning. Since constuction of thus detailed overall models leads to inhibitive dimensions one has to construct partial models. Thus, the notion of systems of models emerges.

This paper presents a version of the detailed Generalized Regional Agriculture Model GRAM implemented at IIASA for the Upper Notei rivershed region in Poland. The capacity of the model as a development planning did in agricultural policy definition is especially considered in the light of its potential and actually obtained results. The model describes basic agrotechnical, resource and financial aspects of regional agriculture. Having large dimensions (more than 3500 variables and 950 constraints) it constituted a test of operationability of such models run on advanced mathematical programming software, a test which gave positive results.

The model is run for various objective functions. Its detailedness allows to establish connections with other regional or national models, and with models for particular aspects (e.g. plant growth and requirements). A number of non-trivial conclusions were drawn from GRAM's results. Thus, in spite of its inherent intellectual simplicity the model can be a reliable decision-aiding tool in plan elaboration and an efficient element of a model system. Experiences gained in this implementation of GRAM served afterwards in construction of its version for the Silistra region in Bulgaria.

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Abstract. The use of a large-scale LP agricultural model for supporting the policy design process is presented. The model determines the agricultural crop and livestock specialization in a detailed, disaggregated form, i.e. distributed over subregions, properties, soil qualities, technologies, etc. and basic financial and material flows, all in given natural conditions, e.g. soil qualities, and available resources, e.g. manpower, machinery, capital, etc. The policy is meant in terms of imposed price structure and resource distribution. The use of information obtainable from both primal and dual solution is shown. The results of implementation for a region in Poland are presented.

Keywords. Agriculture, large-scale systems, linear programming, policy making.

INTRODUCTION

Problems of regional development become more and more important throughout the world. The reasons are manifold. On one hand, regions - even in one country - may differ in their development levels and capacities to such an extent that a specific analysis may be needed. On the other hand, the economic growth cannot be evidently meant without its geographical dimension, not only in the sense of sectoral locational considerations, but also through intersectoral localized analysis, whether of growth pole or industrial complex type.

An efficient planning and monitoring of regional growth requires conjoint consideration of all essential aspects, e.g. economic, social, managerial, technological, etc., with regard to the region and its environment. Such an approach, known as the Integrated Regional Development (5) is increasingly postulated to be the only reasonable and most efficient by both theorists and practitioners.

The above is particularly difficult in agricultural regions of most countries. On one hand, the subsidies, externally imposed and not always economically justified prices, etc. may prohibit an analysis in purely economic terms. On the other hand, some non-economic problems, e.g. out-migration, aging of the rural population, may become critical so that actions may be required not being compatible with the economic rationale. The situation is even worse in mixed economies, i.e. with three types of land property: state-owned, collective and private. The intersts and policy spheres may therefore be quite different and the socio-economic interrelations - extremely intricate.

One of the most important issues in regional research is the analysis and design of appropriate policies, most efficient from the social point of view, meant as volumes of resources to be allocated to particular subregions, forms of property, etc. Evidently, to properly devise a policy in such a complicated situation, a detailed description of socio-economic reality is compulsory, which in turn leads to large-scale models, forcibly linear.

The purpose of the paper is to present such a large-scale LP model of regional agriculture. The model is implemented for a region in Poland currently under a development program and run on DATAMA/SESAME LP system (4). The model incorporates both agroctechnical and economic elements and determines the agricultural specialization in given conditions, natural and those resulting from the current policy. Thus, an impact of a policy may be evaluated. Moreover, the analysis of results and additional information obtainable from the solution, e.g. shadow prices, unused resources input costs, etc. may efficiently be employed for the policy design.

BRIEF DESCRIPTION OF THE MODEL

The model will be briefly presented in terms of: indices, coefficients, bounds, decision variables, constraints and objective functions.

Indices

All the existing indices and their values and meanings used in the implementation study reported are as follows:

i - kind of crop (1 - wheat, 2 - rye, 3 - barley, 4 - oats, 5 - other grains, 6 - sugar beets, 7 - potatoes, 8 - maize, 9 - forage beets, etc., 10 - beans, etc., 11 - clover, etc., 12 - linen, etc., 13 - meadows and pastures products);

$I = \{i\}$ - set of all crops, w - index of crop group $I^w (I^1 = \{1,2,3,4,5\}$, $I^2 = \{6,7\}$, $I^3 = \{8,9\}$, $I^4 = \{10,11\}$, $I^5 = \{12\}$, $I^6 = \{13\}$;

j - kind of livestock (1 - milk cows, 2 - other cattle, 3 - sows, 4 - other pigs, 5 - horses, 6 - sheeps, 7 - fowl);

k - specialization of livestock breading (e.g. for meat, wool, eggs, etc.) - here k = 1;

m - kind of livestock product (1 - meat, 2 - leather, 3 - milk, 4 - eggs, 5 - wool);

r - subregion corresponding e.g. to an administrative division - here r = 1,2,3; denoted by B,W,K, respectively;

n - feed components (1 - nutrition units, 2 - proteins, 3 - dry mass, 4 - green mass, 5 - hay, 6 - preserves, 7 - grain rests, 8 - starchy roots, 9 - potatoes, 10 - other crops, 11 - milk);

l - type of market for purchasing/selling commodities (1 - internal state, 2 - internal private, 3 - export);

p - economy (land ownership) (1 - state-owned, 2 - collective, 3 - private; denoted by S,C,P, respectively);

s - technology of crop raising (1 - good present-day, 2 - highly efficient with a high fertilizer use but without irrigation, 3 - as 2, but with irrigation; denoted by P,F,I, respectively);

α - land quality (1 - weak, 2 - medium minus, 3 - medium plus, 4 - good; denoted by W,M,P,G, respectively);

s' - technology of livestock breeding - here s' = 1;

f - type of fertilizer (1 - N, 2 - P, 3 - K, 4 - Ca);

β_i - second crop (the best or only successor for the first crop i).

Coefficients

The following coefficients are included:

$a_{fiprs\alpha}$ - demand of fertilizer f to produce unit of crop i on land α in subregion r in economy p with technology s,
$\hat{a}_{fjks'}$ - production of fertilizers through manure,
$b_{iprs\alpha}$ - labor requirement in crop production,
$b_{jkprs'}$ - labor requirement in livestock breeding,
$c_{iprs\alpha}$ - capital (investment) demand, without technology tranformation,
$\bar{c}_{iprs\alpha}$ as above, with technology improvement,
$c_{jkprs'}$ - capital (investment) demand, without technology transformation,
$\bar{c}_{jkprs'}$ - as above, with technology improvement,
$d_{iprs\alpha}$ - water demand for crop raising, total,
$\hat{d}_{iprs\alpha}$ - as above, for peak period,
$d_{jkprs'}$ - water demand for livestock breeding, total,
$\hat{d}_{jkprs'}$ - as above, for peak period,
$e_{iprs\alpha}$ - machinery demand for crop production,
$f^{min,max}_{njk}$ - minimum and maximum demand for feed components for livestock,
g_{in} - contents of feed components in crops,
g_{mn} - contents of feed components in livestock products,
$h_{mjkps'}$ - livestock product yields,
n_i - contents of nutrition units in crops,
n_m - contents of nutrition units in livestock products,
p^1_i - unit price of home-produced crops on market 1,
p^1_m - unit price of home-produced livestock products on market 1,
p^{imp}_{il} - unit price of crops purchased for forage on market 1.
$\bar{p}^{imp}_{il}$ - as above, for human consumption,
p^{imp}_{ml} - unit price of livestock products purchase for human consumption on market 1,
$s_{iprs\alpha}$ - costs of crop production, with seeds and fertilizers,
$s_{jkprs'}$ - costs of livestock production, without forage,
$u_{iprs\alpha}$ - yields of crops,
$u^1_{iprs\alpha}$ - yields of crops raised as secondary,
W_{pr} - minimal income per capita.

Bounds

The following lower and upper bounds are used:

B - labor force, total,

B_{pr} - as above, for property types and subregions,

C - maximum external and internal capital (investment) in the region,

C_{pr} - as above, for property types and subregions,

D - total annual water volume available,

$\hat{D}$ - as above, for peak period,

D_{pr} - annual water volume available, for property types and subregions,

$\hat{D}_{pr}$ - as above, for peak period,

E - total available machinery,

$F_i^{min,max}$ - minimum and maximum human consumption of crops,

$F_{ipr}^{min,max}$ - minmum and maximum production of crops, for property types and subregions,

G_f - maximum available amount of fertilizer f,

G_{fpr} - as above, for property types and subregions,

H_{il} - maximum crop purchases for forage on market 1,

I_{il} - maximum crop purchases for human consumption on market,

I_{ml} - maximum purchases of livestock products on market 1,

$L_{wpr}^{min,max}$ - minimum and maximum area for crop group w (due to crop rotation),

$L_{pr\alpha}^{min,max}$ - minimum and maximum area of given soil quality,

$L_{prs\alpha}^{min,max}$ - minimum and maximum area of transformable land (into technology s),

L_{pr} - area of arable land,

L_{pr}^{m} - area of meadows and pastures,

$M_{jpr}^{min,max}$ - minimum and maximum breeding of livestock.

Decision variables

$X_{iprs\alpha}$ - volume of primary crop production,

$Y_{iprs\alpha}$ - volume of secondary crop production,

W_{ipr} - own consumption of crops by population,

Z_{ipr} - as above, by livestock,

$X_{jkprs'}$ - livestock bred,

W_{mpr} - own consumption of livestock products by population,

Z_{mpr} - as above, by livestock,

P_{iprl} - purchases of crops for forage,

Q_{iprl} - purchases of crops for population,

Q_{mprl} - purchase of livestock products for population,

R_{iprl} - sale of crops,

R_{mprl} - sale of livestock products.

Constraints

The description of constraints is divided into the following groups concerning particular aspects:

1. Land use

a) availability of arable land

$$\sum_{\substack{i\varepsilon I-I^6 \\ s,\alpha}} \frac{X_{iprs\alpha}}{u_{iprs\alpha}} = L_{pr} \qquad (1)$$

b) availability of land of particular quality

$$L_{pr\alpha}^{min} \le \sum_{i,s} \frac{X_{iprs\alpha}}{u_{iprs\alpha}} \le L_{pr\alpha}^{max} \qquad (2)$$

c) availability of arable land for crops I^w, w = 1,...,5, due to crop rotation

$$L_{wpr}^{min} \le \sum_{\substack{i\varepsilon I^w, \\ s,\alpha}} \frac{X_{iprs\alpha}}{u_{iprs\alpha}} \le L_{wpr}^{max} \qquad (3)$$

d) availability of transformable land, i.e. s = 2,3

$$L_{prs\alpha}^{min} \le \sum_{i} \frac{X_{iprs\alpha}}{u_{iprs\alpha}} \le L_{prs\alpha}^{max} \qquad (4)$$

e) availability of meadows and pastures

$$\sum_{\substack{i\varepsilon I^6, \\ s,\alpha}} \frac{X_{iprs\alpha}}{u_{iprs\alpha}} \le L_{pr}^{m} \qquad (5)$$

f) availability of land for secondary crops

$$\sum_{\substack{i^*\varepsilon\beta_i, \\ s,\alpha}} \frac{Y_{i^*prs\alpha}}{l_i , u_{i^*prs\alpha}} - \sum_{s,\alpha} \frac{X_{iprs\alpha}}{u_{iprs\alpha}} \le 0 \qquad (6)$$

2. Crop and livestock product balances

a) crops

$$\sum_{s,\alpha} (X_{iprs\alpha} + Y_{iprs\alpha}) - W_{ipr} - Z_{ipr} - \sum_{l} R_{iprl} = 0 \qquad (7)$$

b) livestock products

$$\sum_{j,k,s'} h_{mjkps'} X_{jkprs'} - W_{mpr} - Z_{mpr} - \sum_{l} R_{mprl} = 0 \qquad (8)$$

3. Forage balances

a) for state farms (p = 1)

$$\begin{aligned}\sum_{j,k,r,s'} f^{min}_{njk} X_{jkprs'} &\le \sum_{i,r} g_{in} Z_{ipr} + \\ &+ \sum_{i,r,l} g_{in} P_{iprl} + \sum_{m,r} g_{mn} Z_{mpr} \le \\ &\le \sum_{j,k,r,s'} f^{max}_{njk} X_{jkprs'} \qquad (9)\end{aligned}$$

b) for collective and private farms (p = 2,3)

$$\begin{aligned}\sum_{j,k,s'} f^{min}_{njk} X_{jkprs'} &\le \sum_{i} g_{in} Z_{ipr} + \\ &+ \sum_{i,l} g_{in} P_{iprl} + \sum_{m} g_{mn} Z_{mpr} \le \\ &\le \sum_{j,k,s'} f^{max}_{njk} X_{jkprs'} \qquad (10)\end{aligned}$$

4. Limits of population consumption

a) crops

$$F^{min}_{i} \le \sum W_{ipr} + \sum_{p,r,l} Q_{iprl} \le F^{max}_{i} \qquad (11)$$

b) livestock products

$$F^{min}_{m} \le \sum_{p,r} W_{mpr} + \sum_{p,r,l} Q_{mprl} \le F^{max}_{m} \qquad (12)$$

5. Production limits

a) crops

$$F^{min}_{ipr} \le \sum_{s,\alpha} (X_{iprs\alpha} + Y_{iprs\alpha}) \le F^{max}_{ipr} \qquad (13)$$

b) livestock

$$M^{min}_{jpr} \le \sum_{k,s'} X_{jkprs'} \le M^{max}_{jpr} \qquad (14)$$

6. Resource constraints

a) labor

$$\begin{aligned}&\sum_{i,s,\alpha} b_{iprs\alpha} (X_{iprs\alpha} + Y_{iprs\alpha}) + \\ &+ \sum_{j,k,s'} b_{jkprs'} X_{jkprs'} \le B_{pr} \qquad (15)\end{aligned}$$

$$\begin{aligned}&\sum_{i,p,r,s,\alpha} b_{iprs\alpha} (X_{iprs\alpha} + Y_{iprs\alpha}) + \\ &+ \sum_{j,k,p,r,s'} b_{jkprs'} X_{jkprs'} \le B \qquad (16)\end{aligned}$$

b) annual water

$$\begin{aligned}&\sum_{i,s,\alpha} d_{iprs\alpha} (X_{iprs\alpha} + Y_{iprs\alpha}) + \\ &+ \sum_{j,k,s'} d_{jkprs'} X_{jkprs'} \le D_{pr} \qquad (17)\end{aligned}$$

$$\begin{aligned}&\sum_{i,p,r,s,\alpha} d_{iprs\alpha} (X_{iprs\alpha} + Y_{iprs\alpha}) + \qquad (18) \\ &+ \sum_{j,k,p,r,s'} d_{jkprs'} X_{jkprs'} \le D\end{aligned}$$

c) water in peak period

$$\begin{aligned}&\sum_{i,s,\alpha} \hat{d}_{iprs\alpha} (X_{iprs\alpha} + Y_{iprs\alpha}) + \\ &+ \sum_{j,k,s'} \hat{d}_{jkprs'} X_{jkprs'} \le \hat{D}_{pr} \qquad (19)\end{aligned}$$

$$\begin{aligned}&\sum_{i,p,r,s,\alpha} \hat{d}_{iprs\alpha} (X_{iprs\alpha} + Y_{iprs\alpha}) + \\ &+ \sum_{j,k,p,r,s'} \hat{d}_{jkprs'} X_{jkprs'} \le \hat{D} \\ &\qquad (20)\end{aligned}$$

d) machinery

$$\sum_{i,p,r,s,\alpha} e_{iprs\alpha} (X_{iprs\alpha} + Y_{iprs\alpha}) \le E \qquad (21)$$

e) fertilizers

$$\begin{aligned}&\sum_{i,s,\alpha} a_{fiprs\alpha} (X_{iprs\alpha} + Y_{iprs\alpha}) - \\ &- \sum_{j,k,s'} \hat{a}_{fjks'} X_{jkprs'} \le G_{fpr} \qquad (22)\end{aligned}$$

$$\begin{aligned}&\sum_{i,p,r,s,\alpha} a_{fiprs\alpha} (X_{iprs\alpha} + Y_{iprs\alpha}) - \\ &- \sum_{j,k,p,r,s'} \hat{a}_{fjks'} X_{jkprs'} \le G_{f} \qquad (23)\end{aligned}$$

7. Purchase limits

a) crops for forage ($i \in I - I^6$)

$$\sum_{p,r} P_{iprl} \le H_{il} \qquad (24)$$

b) crops for population ($i \in I - I^6$)

$$\sum_{p,r} Q_{iprl} \le I_{il} \qquad (25)$$

c) livestock products for population

$$\sum_{p,r} Q_{mprl} \le I_{ml} \qquad (26)$$

8. Sale limits

a) crops ($i \in I - I^6$)

$$\sum_{p,r} R_{iprl} \le \bar{I}_{il} \qquad (27)$$

b) livestock products

$$\sum_{p,r} R_{mprl} \leq \bar{I}_{ml} \qquad (28)$$

9. Financial limits

a) capital investments

$$\sum_{i,s,\alpha} C_{iprs\alpha} (X_{iprs\alpha} + Y_{iprs\alpha}) + \sum_{i,s,\alpha} \bar{c}_{iprs\alpha} X_{iprs\alpha} + \sum_{j,k,s'} c_{jkprs'} X_{jkprs'} \leq C_{pr} \qquad (29)$$

$$\sum_{i,p,r,s,\alpha} c_{iprs\alpha} (X_{iprs\alpha} + Y_{iprs\alpha}) + \sum_{i,p,r,s,\alpha} \bar{c}_{iprs\alpha} X_{iprs\alpha} + \sum_{j,k,p,r,s'} c_{jkprs'} X_{jprs'} \leq C \qquad (30)$$

b) minimal income for collective and private farms

$$\sum_{i,l} P^{1}_{i} R_{iprl} + \sum_{m,l} P^{1}_{m} R_{mprl} - \sum_{i,s,\alpha} s_{iprs\alpha} X_{iprs\alpha} + - \sum_{j,k,s'} s_{jkprs'} X_{jkprs'} - \sum_{i,l} P^{imp}_{il} P_{iprl} + - \sum_{i,l} \bar{P}^{imp}_{il} Q_{iprl} - \sum_{m,l} P^{imp}_{ml} Q_{mprl} \geq W_{p} B_{pr} \qquad (31)$$

Objective functions

The objective function given below express, roughly speaking, some regional output in monetary or non-monetary terms.

a) regional profit

$$\sum_{i,p,r,l} P^{1}_{i} R_{iprl} - \sum_{i,p,r,s,\alpha} s_{iprs\alpha} X_{iprs\alpha} + \sum_{m,p,r,l} P^{1}_{m} R_{mprl} + - \sum_{j,k,p,r,s'} s_{jkprs'} X_{jkprs'} - \sum_{i,p,r,l} P^{imp}_{il} P_{iprl} - \sum_{i,p,r,l} \bar{P}^{imp}_{il} Q_{iprl} - \sum_{m,p,r,l} P^{imp}_{ml} Q_{mprl} \qquad (32)$$

b) agriculture production in monetary terms

$$\sum_{i,p,r,s,\alpha} P^{1}_{i} X_{iprs\alpha} + \sum_{m,j,k,p,r,s'} P^{1}_{m} h_{mjkps'} X_{jkprs'} + - \sum_{i,p,r,l} P^{imp}_{il} P_{iprl} - - \sum_{i,p,r,l} \bar{P}^{imp}_{il} Q_{iprl} - - \sum_{m,p,r,l} P^{imp}_{ml} Q_{mprl} \qquad (33)$$

c) agriculture production in nutrition units

$$\sum_{i,p,r} n_{i} \left[\sum_{s,\alpha} X_{iprs\alpha} - \sum_{l} (P_{iprl} + Q_{iprl}) \right] + \sum_{m,p,r} n_{m} \left(\sum_{j,k,s'} h_{mjkps'} X_{jkprs'} - - \sum_{l} Q_{mprl} \right) \qquad (34)$$

d) production of livestock products in monetary terms

$$\sum_{m,p,r,l} P^{1}_{m} R_{mprl} - \sum_{m,p,r,l} P^{imp}_{il} Q_{mprl} - \sum_{i,p,r,l} P^{imp}_{iprl} \qquad (35)$$

e) production of livestock products in nutrition units

$$\sum_{m,j,k,p,r,s'} n_{m} (h_{mjkps'} X_{jkprs'} - - \sum_{l} Q_{mprl}) \qquad (36)$$

f) export production in monetary terms

$$\sum_{\substack{i,p,r \\ l=3}} (P^{1}_{i} R_{iprl} - \bar{P}^{imp}_{il} Q_{iprl} - P_{iprl}) + \sum_{\substack{m,p,r \\ l=3}} (P^{1}_{m} R_{mprl} - P^{imp}_{ml} Q_{mprl}) \qquad (37)$$

SHORT PRESENTATION OF THE RESULTS

The model as described in the previous section resulted in a large-scale, LP problem of approx. 3500 columns (variables) and approx. 950 rows (constraints), with a difficult structure and a dense matrix (> 4%). A special LP System for handling large LP problems was, therefore, needed. Such a system, the DATAMAT/SESAME (4) works at the CNUCE Computing Center in Pisa, Italy on an IBM Series 370 computer. Thus, the model was run at the International Institute for Applied Systems Analysis in Laxenburg, Austria using a telex line to Pisa. Such a mode has proved to be surprisingly efficient and virtually transmission-error-free. The generation of the problem was relatively difficult and time consuming, though greatly simplified by the DATAMAT facilities. The running proceeded quite fast due both to the efficiency of SESAME and to the possibility of the interactive work it offers.

Some of the more important results obtained from the model in the implementation study will be briefly described here. Short characteristics of numerical results obtained for the three objective functions a., b., and c are given in Table 1. These results illustrate policies undertaken considering costs and without cost consideration.

It is, however, also important to take into account qualitative features of solutions.

Objective function / Result	a.	b.	c.
Areas under given technologies, in %			
S = 1: present	96	52	49.3
S = 2: intensive	0.1	6.7	9.3
S = 3: irrigated	3.9	41.3	41.4
Production of main crops, in 10^3 tons			
wheat	115.6	131.9	132.2
rye	87.2	149.7	149.5
sugar beets	889.2	898.9	899.0
potatoes	1101.5	1129.3	1132.3
meat	28.6	28.0	28.0
milk	160.0	160.0	163.4

Table 1. Some results for the first three objective functions.

Qualitative results are to be understood here in terms of (short) listings from the SESAME/DATAMAT LP System (4). They, roughly speaking, give the following:

1. for constraints (rows): status (at the basis, lower and upper limit), value (activity), slack. lower and upper limit, dual activity;
2. for variables (columns): value (activity), input cost, lower and upper limit, reduced cost.

The above results may now be partitioned into the two following groups. The first contains the "real" results, i.e. concerning physically existing entities, as the values of constraints and variables. The second one contains information on "artificial", not physically existing entities, as e.g. slacks, dual activities, input costs, reduced costs, etc. Thus, the first results give a pattern of production immediately understandable by e.g. decision makers, while the second ones provide data needed to a greater degree by analysts to perform some further analysis.

The policy design considered must evidently be based on those two kinds of information. Below, only the results of the first group will, however, be presented while the second ones will be discussed in the next section devoted to the policy design.

In the model's runs reported, the regional profit (32) was assumed to be the objective function.

Proceeding to the presentation of the results obtained, let us begin with the specialization determined. The crop specialization is shown in Table 1, the symbols used are as given in the "Indices" part of Section 2 and the dominating (if any) properties, subregions, etc. are underlined. Some of the more important conclusions are:

1. Grains are grown mostly on weak and medium quality soils, while better soils are predominantly used for forage crops. This results from a relatively high emphasis on sufficient livestock production.
2. More advanced technologies, i.e. fertilized and irrigated, are not widely employed; actually only for forage crops. The reason is, first, that the lowest technology is assumed to be relatively good. Second, since the objective function is of the net profit type, then the areas under a more advance technology, e.g. irrigation, are to be meant as those, where this is strictly economically justified under given prices and costs.

The livestock specialization is shown in Table 2. The specialization on cattle is manifested in the private sector and subregion B and on horses and sheep also in the private sector and the subregions B, W, and B, K, respectively. The tightest constraints were: the volume of fertilizer P, labor in some subregions and private sector, minimal income, in particular in the collective sector, and maximum sale.

The region proved to be self-sufficient with respect to all the important products. Moreover, strong sale orientation occurred.

SUPPORTING POLICY DESIGN THROUGH MODEL'S RESULTS

The problem of designing a proper policy, meant mainly in terms of a price structure and resource allocation pattern, is extremely difficult in any real economic activity. In the agriculture the situation is even worse due to complicated and interwoven economic, demographic, social, etc. interconnections in most rural regions.

Facing those difficulties, authorities responsible for the policy design have attempted for a long time to use some more formal aids, e.g. mathematical models. However, it should be stressed that the models were not intended to replace the human policy designer, although they played an important role by making it possible, e.g. to objectively review many possible variants, produce analytic or synthetic auxilliary data, etc. Roughly speaking, they add some extremely important precision and objectivity to the policy design.

According to the above perspective, the aim of this section is not to give a formal algorithm for policy design, but rather some indications as how to use more important information obtained from the model's results. First, the use of "real" data will be illustrated, while some remarks will be given later as to what may be gained from "artificial" data.

The following main issues should be considered:

1. Are the resources sufficient? The resource constraints are evidently satisfied at optimum, thus the slacks, i.e. unused resources, and their distribution over subregions and properties are actually of interest. The slack value may indicate, what resource should be added, for instance, the results obtained show a lack of P fertilizer. The distribution of slacks is also crucial indicating a need for shifting some resource from one subregion or property to another. Thus, if the policy is efficiency-oriented, then an unequal distribution is usually advantageous while for an equity-oriented policy a more equal distribution would probably be better.

2. If some resource is sparse, then what about its substitution? If it turns out that some resource is sparse, then the following question emerges: is it better to increase this resource to to increase its substitution? The main example here is the substitution of labor for machinery. Unfortunately, in most cases, this is unidirectional, because the agriculture labor force cannot practically be increased, it actually decreases. Thus, there often remains an increase of machinery. However, the extra machinery could not cost very much and need more imported fuel. This should be taken into account, e.g. by analyzing if the cost of stopping out-migration by higher salaries, better housing, etc. would not be lower.

3. Is the specialization determined compatible with that envisaged for the region, subregion or property by higher-level plans (e.g. national)? The model, concerning the region as a relatively independent unit, may be somewhat "short-sighted", i.e. may determine a specialization being optimal for e.g. the region itself, but not for the region as a part of a macroregion or country. Thus, the policy must induce such a specialization, which is a confluence of that resulting from the model and that resulting from higher-level plans.

4. Is the objective function adequate? The agricultural price-cost structure usually does not reflect real economic relations. Moreover, subsidies may also disturb the "sound" economic behavior. Thus, the use of monetary-type objective functions, e.g. the regional profit, may be inadequate leading to wrong results. In turn, in the physical-output-type objective functions, the financial reality determining to a large extent the behavior of producers does not find a proper place. Thus, the best way would be to apply a multicriterial approach with both. This is currently under development, as indicated in the concluding remarks.

As mentioned previously, the information concerning the "physically non-existing" entities also plays an important role. This concerns mostly the values of dual activities and input costs. The first one gives some relative importance on particular constraints. For instance, the relative importance of P fertilizers proved to be very high. The input cost gives some limits as to the relation of production costs - price, as well as sale income - production costs. Thus, this information helps to better perform the analysis mentioned earlier. However, it is more useful for analysts than decisionmakers.

Thus, as shown in this section, the model may give valuable information supporting the policy design process. One should, however, always be aware of the model's role in the process. The model cannot replace any human decisionmaker, but may add an important quantitative element to the predominantly qualitative policy design.

DYNAMICS

The model is meant for a time horizon of 3-6 years, which is mainly conditioned by the price/cost structure. As far as forecasting applications are concerned, a number of runs for various such structures were made. Since the model does not describe a project, eventually containing also construction activities and food processing industry development, the dynamic considerations were not deemed necessary at the first stage. Indeed, the only essential dynamic aspects here are herd structure and financial relations. The possibility of dynamizing these two aspects are envisaged. Two options are open. The first is an endogenous addition of a number of variables and some constraints, which would not entail great expansion of the model (approx. 6-8 variables for cattle and 3-4 for pigs, for each p and r, with the number of constraints depending upon the time horizon). The second would rely upon an external need structure model for specification of GRAM limitations. In any case, the time horizon for such a dynamic optimization model of linear dynamic programming variety cannot be greater than the 5-6 years mentioned above. Furthermore, over the time horizon T adopted, the crop production would be treated as static, i.e. taken T times. The most important results obtained from the dynamic model will concern initial and final conditions on the state: i.e. resources and yields. Explicit dependence upon and sensitivity to such conditions over a long period, especially for financial purposes is crucial for policy making.

CONCLUDING REMARKS

As shown in the paper, a detailed agricultural model may be a suitable tool to support a policy design procedure. One of the decisive reasons is the policymakers-oriented and not analyst-oriented detailedness of the model, i.e. that the activities (variables and constraints) are disaggregated into subregions, properties, soil, qualities, technologies, etc., hence the categories existing in the reality and in terms of which the policymakers think and proceed. Thus the results of the model may be used by appropriate authorities while designing a policy in a "direct" and relatively easy way.

The second important advantageous feature of the model is that it involves both agrotechnical and economic aspects of the agricultural production. They are not separable in any case and what is done in most other models, i.e. that either the first sphere or the second or - at best - both, but separately, are considered, may lead to unsuitable results, hence may induce an improper policy

Although the model's version described and currently run is advanced enough and gives satisfying results, some further improvements are evidently possible. As for now, under study are the model's variants covering: an uncertainty resulting from unpredictable climatic changes, price fluctuations, etc. and multicriterial aspects of agriculture production. Both issues above seem to make the model adequate to the reality, hence providing a better tool to support policy design procedures.

No.	Crop	Property	Subregion	Soil	Technology
1	wheat	S	B,K,W	W,M,P	P
2	rye	C,P	B,K,W	W,M,P	P
3	barley	S,P	B,W,K	M,P,G	P
4	oats	S,C	B,K	W,M,P	P
5	other grains	P	B	W	P
6	sugar beets	S,C,P	B,W,K	P,G	I
7	potatoes	S,C,P	B,W,K	W,M,P,G	P,F
8	maize	S,C,P	B,W,K	M,P,G	P
9	forage beets, etc.	C,P	B,W,K	M,P,G	P
10	beans, etc.	C,P	B,W,K	W,M,P	P
11	clover, etc.	S	B,K	W	P
12	linen, etc.	C,P	B,W,K	M,P,G	P
13	meadows	S,C,P	B,W,K	P,G	F,I

Table 2. Crop specialization

No.	Livestock Type	Property	Subregion
1	milk cows	S,C,P	B,W,K
2	other cattle	S,C,P	B,W,K
3	pigs	C,P	BWK
4	horses	P	BW
5	sheep	P	BK
6	fowl	S,C,P	BWK

Table 3. Livestock specialization

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