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Optimization of Prospective Plans of an Agricultural Zone by means of Mathematical Methods and Electronic Computers*

This paper presents an economic-mathematical model for optimizing the prospective plans of co-operative agricultural production within a natural economic zone.

The improvement of the planning methods of economy has played an important part in the proceedings of the National Conference of the Romanian Communist Party.

The principles and planning methodology aproved by the National Conference of the R.C.P. also assign the introduction of modern mathematical methods in the domain of agriculture.

The aim of this study is to present a mathematical model that can be used in the planning of agricultural enterprises or of zones, and to point to the methodology of computation for the technical-economic coefficients used. Based on the presentation of concrete computations from the co-operative agriculture of the counties of Timiş and Arad, carried out on the "Elliott 803 B" electronic computer of the Hunedoara Iron and Steel Aggregate Works, the advantages deriving from the application of these methods also in the domain of agricultural production, territorial distribution and planning are pointed out. The following methodology was used for the solution:

1. TECHNICAL-ECONOMIC STUDY

The technical-economic study was based on the economic data of a number of production agricultural cooperatives, the agricultural-economic

* The programme for solving this problem with the "Elliott 803 B" computer was elaborated by G. Weisz and C. Fabian

analysis of the cadastral survey, as well as the prospective plans set up by each co-operative down to 1970.

Starting from the fact that a great variety of natural and social economic conditions are found in the western plain of Romania, the delimitation of natural economic zones meant to comprise co-operatives enjoying similar conditions has been considered necessary. This delimitation was made in accordance with the following factors:

— Natural conditions such as: soil fertility, relief, structure of the manner in which the land is used and frequency of natural hayfields and pastures;

— Degree of territorial distribution and development of the production agricultural co-operatives and tractor and machines stations technical-materials basis;

— Labour resources;

— Transportation means and network.

Such a zone, located in the counties of Timiş and Arad, comprises 49 co-operatives in the outmost western plain, having the most fertile soils, a plane relief and affording the possibility for integralmechanization of agricultural work. This zone enjoys very favourable natural conditions for all agricultural crops. Best results are obtained in the culture of maize, sugar-beet, hemp and vegetables. The endowment with tractors and agricultural machinery is generally satisfactory, one tractor being incumbent on 83 ha. of tillable ground. Concomitantly, 43.8 labourers are available for every 100 ha. of tillable ground. The labour resources of the zone are therefore ensured in manpower, having an available stock of about 8 million man/day, computed for a minimum number of 180 m/d for one able person. The mean size of a co-operative in this zone is 2,300 ha.

For the variables of the problem in each zone the following technical-economic and proportionality coefficients have been determined per surface unit and per conventional animal; mean production, labour required yearly and in peak periods, animal traction power required yearly and in peak periods, yearly consumption of nutritious units and digestible protein by categories of fodder, value of gross output, material expenses and value of net output. In view of making up the matrix of each zone the volume of the main production resources has been determined, viz.: tillable surface, manpower total and in peak period, nutritious units and digestible protein to be ensured from natural hayfields and pastures, minimum secured volume of wheat, maize grains, industrial and comestible plants, vegetables, milk, meat and wool.

The technical-economic coefficients have been determined in agreement with the results obtained by the co-operatives in the last three years and taking into account the increase in their degree of mechanizing, fertilizing, as well as the works of land melioration provided in the present 5-year plan. The volume of the resources was established in accordance with the tasks provided by the State plan for 1970 and the necessity to ensure the internal consumption of the production agricultural co-operatives.

2. MATHEMATICAL MODEL AND MATRIX OF THE PROBLEM

Some peculiarities of agricultural production were taken into account in view of elaborating the mathematical model showing the association of the various branches. The production branches have therefore been classified according to the different use of the final product as follows:

— Final branches (X), which ensure most of the commodity production;

— Complementary branches (Z), which allow a more complete use of the production resources and yield a certain volume of commodity production;

— Associated branches (Y), which contribute to the normal production process in the other branches;

— Branches of use (U), within which the efficient use of the by-products from the final and complementary branches is ensured.

The classification adopted was necessary from the economic and even technological standpoint in order that, in the course of the quantitative analysis, not only the production, but also the distribution processes, should be included. Likewise, this classification has been required by the necessity of establishing as correctly as possible the basic variables which, in the system of linear relations, identify the production branches.

Generally, the branches of agricultural production integrate variably in this classification, in keeping with the final aim of production, this aim being required by the specific conditions in each unit.

Frequently the enterprises must produce a great number of products which are obtained either from a single final branch or from several branches. In one case, as in the other, X may be considered as a set whatever in which $(x_1, x_2, ..., x_n)$ are its elements, each defining a final branch. The reasoning is identifical for the branches Z, Y and U, too. The ratios of development of the branches (X, Z, Y, U) depend on the existence of the resources and on the conditions set.

Let us note by:

a_{mx}, a_{mz}, a_{my}, a_{mu}, a_{ix}, a_{iz}, a_{iy}, a_{iu}, — the consumption norms by branch unit of measure (hectares, animals, etc.);

p_x, p_z, p_y, p_u — the productions obtained per measuring unit of branches;

k_x, k_z, k_y, k_u — the total expenses per measuring unit of branches.

w_x, w_z, w_u, w_y, w'_y, w''_y — the ratio coefficients of the branches X, Z, U vs. the associated branch Y;

c_x, c_z, c_y, c_u — the value of the production unit obtained in each branch;

$\overline{X}$ — the variable showing the production volume in branch X, obtained over the secured volume Q_x, for which a production bonus is granted, of e.g. 20% of the selling price ($0.2\ c_x$);

$\overline{\overline{X}}$ — the variable showing total working expenses.

Besides the main production in branches X, Z, Y, there also results a gross secondary production: $s_x X$, $s_z Z$, $s_y Y$, which can be turned to account:

— either by the branch of use U which consumes, per branch unit, the quantity v_x, v_z, v_y of the secondary production;

— or by selling the quantities of secondary commodity production yielded by the respective branches X', Z', Y', at the selling price of the secondary products c'_{sx}, c'_{sz}, c'_{sy}; resources in the quantities a'_{mx}, a'_{mz}, a'_{my} and a'_{ix}, a'_{iz}, a'_{iy} will be consumed per unit of secondary products and the expenses k'_x, k'_z, k'_y will be made.

For the normal development of the production process in the final branches X, the associated branches Y are required; for the optimum turning to account of the resulting secondary production the branches of use U are resorted to; finally, for the complete and efficient use of the production resources in all the periods of the production process, the complementary branches Z must also be taken into account. In this case, which is the most frequent in practice, the economic-mathematical model of the association of agricultural production branches in the socialist agricultural entreprises is the following:

optimize

$$[\text{Max}]\, f = c_x p_x X + c_z p_z Z + c_y p_y Y + c_u p_u U + 0.2 c_x \overline{X} + \\ + c_{sx'} X' + c_{sz'} Z' + c_{sy'} Y' - \overline{\overline{X}}$$

in the conditions

1) $X + Z + Y + U = S$;

2) $a_{lx} X + a_{lz} Z + a_{ly} Y + a_{lu} U + a_{lx'} X' + a_{lz'} Z' + a_{ly'} Y' \leqslant L$;

3) $a_{ix} X + a_{iz} Z + a_{iy} Y + a_{iu} U + a_{ix'} X' + a_{iz'} Z' + a_{iy'} Y' \leqslant l_i$

4) $p_x X - \overline{X} = Q_x$

5) $k_x X + k_z Z + k_y Y + k_u U + k_{x'} X' + k_{z'} Z' + k_{y'} Y' - \overline{\overline{X}} = 0$

6)
$$w_x X - w_y Y \gtrless 0;$$
$$w_z Z - w_{y'} Y \gtrless 0;$$
$$w_u U - w_{y''} Y \gtrless 0;$$

which, in case conventional units are used, become:

$$w_x X + w_z Z + w_u U - (w_y + w_{y'} + w_{y''}) Y \gtrless 0;$$

7)
$$s_x X - v_x U - X' \geqslant 0;$$
$$s_z Z - v_z U - Z' \geqslant 0;$$
$$s_y Y - v_y U - Y' \geqslant 0;$$

which, in case conventional units are used, become:

$$s_x X + s_z Z + s_y Y - (v_x + v_z + v_y)\, U - (X' + Z' + Y') \geqslant 0;$$

8) $X \geqslant 0$; $Z \geqslant 0$; $Y \geqslant 0$; $U \geqslant 0$;

where

S — cultivated surface (agricultural, tillable, etc.);

L — total volume of labour, or other resources;

l_i — volume for peak periods for labour or other resources;

Q_x — secured minimum volume in products of the main branches.

The described system of equations and inequations, which models the economic process of the association of branches comprises:

— basic (main) variables, which indicate the production branches (X, Z, Y, U);

— auxiliary variables, which indicate the production increase of final branches over the secured volume, total expenses and the volume of secondary production turned to account by sales ($\overline{X}$, $\overline{\overline{X}}$, X'; Z'; Y');

— main (objective) constraints which indicate the balance of the production resources (1, 2, 3);

— supplementary (subjective) constraints, which require the certainty of the secured volume for the final branches (4);

— auxiliary (subjective) constraints, which indicate the total working expenses (5), relations in proportionality between branches (6), distribution of secondary production (7), negative character condition of branches (8);

— optimizing function of the system, which is the maximizing of the net income in the conditions set by the constraints.

The matrix of the problem for the surveyed zone of agricultural production is given in the appendix.

3. ANALYSIS AND INTERPRETATION OF THE RESULTS

Consequently to the computation made by means of the "Elliott 803 B" electronic computer of the Hunedoara Iron and Steel Aggregate Works the branches were apportioned as follows:

(wheat)	x_1	= 25,000	ha	
(maize, grains)	x_2	= 22,622	„	
(sugar beet)	x_3	= 9,061	„	
(hemp)	x_4	= 3,650	„	
(tobacco)	x_5	= 900	„	
(early potatoes)	x_6	= 500	„	
(vegetables)	x_7	= 1,300	„	
(cattle)	x_8	= 16,901	conventional	animals
(pigs)	x_9	= 8,051	„	„
(fowl)	x_{10}	= 0	„	„
(maize grain fodder)	x_{11}	= 16,209	ha	
(barley)	x_{12}	= 0	„	
(oats)	x_{13}	= 3,100	„	
(peas)	x_{14}	= 0	„	
(alfalfa, hay)	x_{15}	= 11,226	„	
(maize, silo)	x_{16}	= 946	„	
(forage beet)	x_{17}	= 0	„	
(alfalfa, silo)	x_{18}	= 0	„	

(alfalfa, green mass)	x_{19}	=	6,826 „
(vetch, green mass)	x_{20}	=	0 „
(maize, double culture)	x_{21}	=	0 „
(purchase of succulent fodder)	x_{22}	=	134,500 tons
(purchase of bran)	x_{23}	=	0 „
(traction animals)	x_{24}	=	15,456 pcs.
(auxiliary variable)	x_{25}	=	6,500 tons

Optimizing function: net output = 468,017,834.

By analyzing the results obtained, particularly significant conclusions may be drawn regarding the manner in which the production branches in this zone are associated.

For plant production the following remarks may be made:

— for the culture of wheat the minimum secured volume of 70 thousand tons, required to meet consumption and to satisfy the tasks imposed by the state plan, is ensured; although the relation referring to the secured volume of wheat production provided the possibility of extending that culture, this did not occur, a fact which proves that there are more profitable crops (at the yields forecast for 1970) in the respective zone;

— the culture of maize for grains was sized up to the area required to attain the (secured minimum) volume of 104.9 thousand tons, although the possibility for extension was given, like in the case of wheat;

— with regard to the industrial plants, owing to the high value of net production per hectare, in comparison with the other crops, they have been sized at the maximum allowed limit (13,611 hectares); the culture of tobacco was sized at the maximum level imposed, having a net production about twice that of sugar beet and 2.5 times that of hemp for hemp bundles;

— potatoes were sized at the minimum established limit thus only attaining the minimum secured production volume;

— vegetables, having the highest net production by surface unit, were sized at the upper limit; thus, a quantity of 6,600 tons in excess of the secured production volume, is certain.

With regard to animal production the following aspects can be observed:

— cattle was sized at the limit required to secure the necessary volume of milk and meat established, although the possibility was given to increase the stock;

— fowl, being only conditioned by meat production, was eliminated from the framework of the pig zone; it is appreciated that the low value of net production resulting per complex fowl breeding in the co-operative system contributed to this elimination;

— pig stocks were sized to secure the established guaranteed volume of meat.

The number of cattle amounts to 16,901 individuals, securing a meat production of 1,555 tons; the meat difference up to the required 14,191 tons was completely supplied by pigs, a number of 8,058 conventional pigs resulting as a consequence.

The quantity of traction animals was sized up to the number required to satisfy the animal pairs/days in the peak periods of work, a number of 15,456 individuals resulting therefrom.

Fodder cultures were sized to the surfaces required in view of satisfying the consumption of nutritious principles in agriculture with the established stocks of animals.

In the variant resulting from the electronic computer, the required nutritious principles are secured from the natural hayfields and pastures existing in the zone, as well as from the following cultures: maize, grains, oats, alfalfa hay and green mass, silo maize and sugar beet shavings. Stress is laid on the fact that some crops such as: barley, peas, forage beet, silo alfalfa, green mass vetch, have been eliminated and replaced by a series of other fodder crops which, comparatively, have proved more profitable.

In the fodder balance, the required 190,590,000 nutritious units and 17,325,000 kgr. digestible protein are entirely ensured by the sized fodder cultures.

The existing labour resources, in the peak period, totalling 1,129,167 man/day satisfy the requirement resulting from the sizing of the various branches, totalling 1,026,733 man/day, the use of labour in the peak period being also secured in a proportion of 91%.

By sizing the number of traction animals to 15,465 units, the required animal pairs/days is secured for the peak period.

With respect to the analysis of the computed synthetic economic indicators in comparison with the plans established by the production agricultural co-operatives and the variant computed manually, their aspect is the following:

a. *Gross output per 100 hectares agricultural ground*

V_0 708,000 ..... 100%
V_1 731,000 ..... 101.0%
V_2 739,000 ..... 104.3%

where:

V_0 = variant computed by production agricultural co-operatives;
V_1 = variant computed manually;
V_2 = variant computed by electronic computer.

b. *Net production per 100 hectares agricultural ground*

V_0 = 408,000 ..... 100%
V_1 = 444,000 ..... 105.4%
V_2 = 468,000 ..... 114.7%

c. *Net income per 100 hectares agricultural ground*

V_1 = 309,300 ..... 100%
V_2 = 326,900 ..... 105.6%

d. *Value of commodity production*

$V_0 = 383{,}500$ 100%
$V_1 = 459{,}800$ 108.2%
$V_2 = 496{,}000$ ..... 129.3%.

Considered from the standpoint of culture distribution, it is obvions that the concentration of the agricultural crops in the zones of maximum efficiency is wholly justified. The results presented, when compared with the present distribution, lead to the conclusion that the surface of sugar beet may be increased from 6,842 to 9,561 ha. Likewise, the concentration of an extended surface of maize in this zone appears to be particularly efficient. The sizing of the grain maize surface, 1,000 ha. above the suggestions of the production agricultural co-operatives also taking into the computation a yield of 5,000 kg. grains/ha which it is possible to reach until 1970, will allow to double commodity and total production for this important crop. An important increase of pork production is concomitantly achieved in this zone; as against 8,500 tons forecast by the co-operatives, a quantity of 12,634 tons will be obtained according to the variant computed by means of the electronic computer. Particular importance derives from the fact that the production of fodder has been correlated with animal production. The resulting data show the necessity of increassing fodder surfaces and, particularly, alfalfa for hay and green mass, from the 12,800 ha. suggested by the co-operatives to 18,998 ha.

The increase of commodity and total production, and particularly that of net production, will bear a positive influence both on the accumulation funds and on the consumption funds, determining a substantial increase in the value of the work-day, a fact which will contribute to the increase of co-operative farmers' material incentive.

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ELABORATION DES MEILLEURS PLANS DE PERSPECTIVE POUR UNE ZONE AGRICOLE A L'AIDE DES METHODES MATHEMATIQUES ET DES ORDINATEURS ELECTRONIQUES

L'élévation du niveau de l'organisation et de la direction économique des entreprises agricoles socialistes de Roumanie dépend en grande mesure du perfectionnement du système d'établissement des tâches revenant à chaque entreprise. De pareils problèmes ne sauraient être résolus dans de bonnes conditions qu'à l'aide des méthodes mathématiques et des calculateurs électroniques.

L'ouvrage présente un modèle économique et mathématique du meilleur plan de perspective de l'agriculture coopératiste des départements de Timiş et Arad.

Cet ouvrage est une application concrète de la planification en perspective d'une zone économique et naturelle comprenant 49 coopératives agricoles de production. La solution du problème a été donnée par l'ordinateur électronique ELLIOTT 803-B appartenant au Combinat Sidérurgique de Hunedoara. Plusieurs indicateurs économiques mettent en relief la supériorité et les avantages économiques de l'application des méthodes mathématiques dans la planification de l'agriculture et dans l'établissement du profil des entreprises agricoles.

ОПТИМИЗАЦИЯ ПЕРСПЕКТИВНЫХ ПЛАНОВ СЕЛЬСКОХОЗЯЙСТВЕННОЙ ЗОНЫ ПРИ ПОМОЩИ МАТЕМАТИЧЕСКИХ МЕТОДОВ И ЭЛЕКТРОННЫХ ВЫЧИСЛИТЕЛЬНЫХ МАШИН

Подъем уровня организации и экономического руководства социалистическими сельскохозяйственными предприятиями в Румынии обуславливается в большой степени усовершенствованием системы установления заданий для каждого предприятия. Подобные проблемы могут быть правильно разрешены только при помощи математических методов и электронных вычислительных машин.

Работа представляет математико-экономическую модель для оптимизации перспективного плана в кооперативном сельском хозяйстве округов Тимиш и Арад.

Работа является конкретным применением перспективного планирования для природно-экономической зоны, охватывающей 49 производственных сельскохозяйственных кооперативов. Вопрос был решен при помощи электронной вычислительной машины « Elliott 803 — B» Металлургического комбината Хунедоры. При помощи ряда экономических показателей показываются преимущества и экономические выгоды, которые представляет применение математических методов в планировании сельского хозяйства и в установлении профиля сельскохозяйственных предприятий.

MATRIX OF THE LINEAR RELATIONS SYSTEM OF THE PROBLEM

	Basic and supplementary limits	Wheat X_1	Grain maize X_2	Sugar beet X_3	Hemp X_4	Tabacco X_5	Potatoes X_6	Vegetables X_7	Cattle X_8	Pigs X_9	Fowl X_{10}	Fodder grain maize X_{11}
1	Tillable surface (ha.)	1	1	1	1	1	1	1	0	0	0	1
2	Double crop surface (ha.)	0	0	0	0	0	0	0	0	0	0	0
3	Total labour (man/day)	5.37	40.42	92.95	28.35	338.31	38.69	223.89	49.21	57.80	1.14	40.42
4	Labour in peak period (man/day)	0.16	21.22	1.45	6.55	10.87	8.05	8.87	4.10	4.82	0.10	21.22
5	Total consumption of n.u. (nutritious units)	0	0	0	0	0	0	0	4263	7918	82.7	−5266
6	Total consumption of digestible protein	0	0	0	0	0	0	0	445	789	6.6	−36
7	Consumption of concentrated fodder (n.u.)	0	0	0	0	0	0	0	903	7232	75.4	−5266
8	Consumption of fibrous fodder (n.u.)	0	0	0	0	0	0	0	834	96	2.6	0
9	Consumption of rough fodder (n.u.)	0	0	0	0	0	0	0	7	o	0	0
10	Consumption of succulent fodder (n.u.)	0	0	0	0	0	0	0	1263	218	0.2	0
11	Consumption of green mass (n.u.)	0	0	0	0	0	0	0	1616	372	4.5	0
12	Secured volume of wheat production (t.)	2.8	0	0	0	0	0	0	0	0	0	0
13	Secured volume of maize production (t.)	0	4.637	0	0	0	0	0	0	0	0	0
14	Limit surface of industrial plants (ha)	0	0	1	1	1	0	0	0	0	0	0
15	Limit production of tobacco (t).	0	0	0	0	1.1	0	0	0	0	0	0
16	Secured volume of potatoes production (t.)	0	0	0	0	0	10	0	0	0	0	0
17	L mit surface of potatoes (ha.)	0	0	0	0	1	0	0	0	0	0	0
18	Secured volume of vegetables production (t.)	0	0	0	0	0	0	22	0	0	0	0
19	Limit surface of vegetables (ha.)	0	0	0	0	0	0	1	0	0	0	0
20	Secured volume of milk production (t.)	0	0	0	0	0	0	0	2.23	0	0	0
21	Secured volume of meat production (t.)	0	0	0	0	0	0	0	0.092	1.568	0.002	0
22	Limit of shavings purchases (t.)	0	0	−14	0	0	0	0	0	0	0	0
23	Limit of bran purchases (kg.)	0	0	0	0	0	0	0	−446	0	0	0
24	Traction animals during peak period (animal pairs days)	0	−4.33	−1.45	−5.55	−0.33	−5.55	−4.30	−0.05	−0.15	−0.001	0
	Function to be optimized	2179	5934	8392	6205	15007	4311	18317	4131	12795	85	−1016

OF OPTIMUM ASSOCIATION OF BRANCHES

Barley X_{12}	Oats X_{13}	Peas X_{14}	Alfalfa hay X_{15}	Silo maize X_{16}	Forage beet X_{17}	Silo alfalfa X_{18}	Green mass alfalfa X_{19}	Green mass autumn vetch -t. X_{20}	Double culture maize X_{21}	Succulent fodder purchases X_{22}	Bran purchases X_{23}	Traction animals X_{24}	Mark	Quantity	Auxiliary variables	Fictitious variables
1	1	1	1	1	1	1	1	1	0	0	0	0	=	101340		31
0	0	0	0	0	0	0	0	−1	1	0	0	0	≤	0		32
5.84	5.23	7.72	12.63	21.33	92.95	2.82	1.29	1.80	4.93	0	0	35.81	≤	7725149		33
0.45	0	0	0	0.49	0	0	0	0	0	0	0	3	≤	129167	3	34
-2322	-3121	-1255	-2750	-8000	-4500	-4250	-4250	-2340	-2340	-140	-0.76	3147	≤	1927440	3	35
-166	-158	-206	-465	-160	-150	-475	-625	-234	-144	-8	-0.098	223	≤	862236	3	36
-2322	-1826	-1255	0	0	0	0	0	0	0	0	-0.76	1131	≤	0		37
0	0	0	-2750	0	0	0	0	0	0	0	0	1133	≤	1510804		38
0	-1295	0	0	0	0	0	0	0	0	0	0	252	≤	0		39
0	0	0	0	-8000	-4500	-4250	0	0	0	-140	0	213	≤	0		40
0	0	0	0	0	0	0	-4250	-2340	-2340	0	0	418	≤	7761960		41
0	0	0	0	0	0	0	0	0	0	0	0	0	≥	70000		42
0	0	0	0	0	0	0	0	0	0	0	0	0	≥	104900	25	43
0	0	0	0	0	0	0	0	0	0	0	0	0	≤	13611	26	44
0	0	0	0	0	0	0	0	0	0	0	0	0	≤	990		45
0	0	0	0	0	0	0	0	0	0	0	0	0	≥	5000		46
0	0	0	0	0	0	0	0	0	0	0	0	0	≤	1000	27	47
0	0	0	0	0	0	0	0	0	0	0	0	0	≥	22000		48
0	0	0	0	0	0	0	0	0	0	0	0	0	≤	1300	28	49
0	0	0	0	0	0	0	0	0	0	0	0	0	≥	37690		50
0	0	0	0	0	0	0	0	0	0	0	0	0	≥	14191	29	51
0	0	0	0	0	0	0	0	0	0	0	0	0	≤	0	30	52
0	0	0	0	0	0	0	0	0	0	0	0	0	≤	0		53
0	0		0	-0.04	-1.45	0	0	0	0	0	0	12.9	=	1965		54
-1445	-1007	-1084	-550	-1017	-2520	-867	-867	-1156	-691	-10	-0.50	-374	=	F. max.		