THE IMPORTANCE OF CROP STRUCTURE OPTIMIZATION IN AGRICULTURAL MANAGEMENT

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Abstract

Mathematical programming models and especially their subclasses - linear programming models - occupy a particularly important place, both in theory and in economic practice being used in various fields. Their application in agricultural management comes as a basis for decisions on the resources allocation or the assignation of a certain crop structure in terms of efficiency aiming at the economic optimum.
The crop structure can also be optimized using other specific methods, the most known being the multiple variants method and the planning program. Model setting is conditioned by the use of electronic computing because the multitude of restrictions and the complexity of mathematical relationships cannot be solved without specific programs.
The solutions obtained are variants that an agricultural farmer can use to achieve the objectives of the unit, being able to immediately see the effects of potential changes in the initially introduced parameters and act accordingly.
Obtaining correct results is conditioned by the prior setting of limit values (minimum outputs, minimum or maximum areas required by certain natural, economic or managerial conditions, weights associated with different crops, etc.) the correct definition of the objective function in order to insure the correctness of the mathematical relationships representing the restrictions imposed and by faithfully scrutinizing the stages specific to the scientific approach in order to achieve the objectives proposed by the agricultural holding or the area concerned.
The paper analyzes the importance of using the linear programming method in agricultural management and exemplifies by presenting a model for optimizing the structure of crops in the Iasi county, highlighting the advantages and limitations of this method as well as possible future research directions.

Key words: linear programming, crop structure optimization, agricultural management, objective function, economic optimum

The crop structure optimization is used in agricultural management through the linear programming method and provides an efficient tool for making agricultural activity more efficient.

Linear programming is a mathematical approach in order to optimize the resources allocation within firm management. Allocation scheme have to comply with the basic requirements of economic activity. It can offer economic and social benefit for the organization but also substantiates the scientific decision (Zhang B., 2016).

Mathematical programming models, and especially their subclasses - linear programming models - owns a particularly important place both in theory and in economic practice. Economic theory has benefited from the interdisciplinary approach that allowed the deepening of the analysis regarding the maximum efficiency of complex systems, the discovery of new concepts of the economic optimum, the improvement of the research and knowledge methods, and the economic practice was enriched with a particularly useful tool for economic analysis and for substantiating decisions.

Optimizing the structure of crops requires the capitalization of natural, economic and social factors of production, under conditions of high economic efficiency (Leuca (Drobotă) Benedicta, 2010), linear programming being used to optimize resource allocation and takes into account two elements: objectives and restrictions (Ungureanu G., 2008).

The linear programming method was used to optimize grain cereal structure. The multitude of concrete economic systems and the multitude of issues of management have created a variety of economic-mathematic representations, called models. Their variety is determined mainly by the structure of the „object" analyzed, the purpose of the research as well as the available information. Linear programming techniques and optimization models in agriculture have been used successfully in recent years to assess the potential impact of

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changes in agricultural policies (Majewski E., Wąs A., 2005).

Agriculture, the basic branch of the national economy, is called upon to provide quantitatively and qualitatively raw materials for the food industry. The structure is optimal when crops provide maximum yield in terms of quantity and range, responding to the demand of the national economy of agricultural products (Drobotă Benedicta et al., 2009).

MATERIAL AND METHOD

The paper describes and applies the linear programming method. This method has the great advantage of allowing the manager to choose the optimal structure from a variety of possible variants. Given the very large amount of computations, the linear programming method implies the use of computational electronics. The optimization of the crop structure by linear programming requires elaboration of the economic-mathematic model, which consists in objective function and restrictions.

The objective function is to optimize the indicator taken into consideration: maximizing the effect or minimizing the effort. Restrictions refer to:

- limitation of resource consumption;
- guaranteeing the achievement of products in the minimum quantities set;
- compliance with succession restrictions;
- returning crops to the same surface;
- extension of double crops.

The problem of linear programming is as follows:

$a_{11}x_1 + a_{12}x_{12} + ... + a_{1i}x_i + ... + a_{1m}x_m = b_1$
$a_{21}x_1 + a_{22}x_2 + ... + a_{2i}x_i + ... + a_{2m}x_m = b_2$
$a_{i1}x_1 + a_{i2}x_2 + ... + a_{ij}x_j + ... + a_{in}x_n = b_i$
.....
$a_{m1}x_1 + a_{m2}x_2 + ... + a_{mj}x_j + ... + a_{mn}x_n = b_m$

An economic process is represented by a system of linear inequalities formed by *m* equations called equations of conditions or restrictions with *n* unknown or variables.

The coefficients aij, i = 1,2, ..., m; j = 1,2, ..., n; are the technic-economic coefficients (eg. expenses)

The unknowns (variables x_j, j = 1,2, ..., n;; are the sizes that are calculated and usually represent the level of production

The objective function is as follows:

$f(x) = c_1x_1 + c_2x_2 + ... + c_jx_j + ... + c_nx_n$

in which, the coefficients c_j, j = 1,2, ..., n; are constant quantities for a given problem, expressed as the value of production, production costs, the unit of measure for the variables (x_j) of the problem.

Taking into account the economic (material) nature of the variables, the conditions of their non-negativity are currently imposed: $x_1 \geq 0$; $x_2 \geq 0$, ...$x_n \geq 0$, since they can not be negative values.

The system of equations must be solved so as to obtain the optimal value (maximum or minimum, as the case may be) of the efficiency function (Brezuleanu S., 2004, Ciurea I. V. *et al*, 2001, Raţiu - Suciu Camelia, 2005).

Several methods are used to optimize crop structure, among which:

- multiple choice method;
- method or planning program;
- linear programming.

The computer software used is represented by the SOLVER function in Microsoft Excel.

RESULTS AND DISCUSSIONS

In linear programming the objective function is to optimize the indicator taken into account: either maximizing the effect (global or net output, profit) or minimizing effort (total expenditure, materials, labor consumption, energy consumption, etc.).

Restrictions refer to the limitation of resource consumption, the guarantee of obtaining products in the minimum quantities set the crops rotation on the same surface The general form of the economic-mathematic model regarding the optimization of the crop structure is:

1) Objective function:

$$F(x) = \sum_{j=1}^{n} C_j x_j \rightarrow \text{optim} \begin{pmatrix} \text{maxim} \\ \text{minim} \end{pmatrix}$$

2) Constraints:

a) limiting resource consumption to the available level:

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i$$

b) guaranteeing the achievement of products in the minimum quantities set:

$$\sum \bar{q}_j \cdot x_j = Q_j$$

c) respecting crop rotation

$$\sum_{j=1}^{n} x_{jp} \geq \sum_{j=1}^{n} x_{jpr}$$

d) returning on the same surface of some crops (sunflower, sugar beet, tobacco, potatoes, peas, etc.)

e) extension of double or anticipated crops

f) the condition of non-negation: $x_j \geq 0$

The meaning of the symbols is:

C_j- the value of the indicator to be optimized;
x_j- branch j size
a_{ij} - resource consumption and j branch sizing unit;
b_i –a available quantity from i resource;
q_j - average yield per ha in branch j
x_{jp} - the surface of good precursor crops;
S - total arable land area;

The validity of the solution obtained by solving the economic-mathematic model with the help of the linear programming is conditioned by the correct formulation of the objective function, in accordance with the objectives of the agricultural enterprise and by the precise highlighting of its production characteristics (Brezuleanu S., 2008).

The study analyzed the crop structure în Iași County. In order to set the framework of the process there were investigated the main indicators regarding agricultural sector.

The total area of the county is 547558 ha, of which the agricultural area in 2014 was 381256 ha. There is an increase in the agricultural area in 2014 compared to 2018 by 0.27%, the most significant growth being for the vineyard areas with (8.52%) and orchards (13, 49%) *(table 1)*

Table 1

The evolution of the agricultural land of Iasi county by use during 2008-2014 (ha)

Item	2008	2009	2010	2011	2012	2013	2014	% 2014/2008
The agricultural area of which, by categories of use:	380231	380155	380117	380085	380080	380080	381256	+0.27
Arable land	255696	255534	255502	255733	255705	255705	256098	+0.16
Pastures	85454	85439	85433	85414	85421	85421	84231	-1.43
Meadow	22324	22257	22260	22003	22007	22007	22465	+0.63
Vineyards	10762	10951	10948	10947	10947	10947	11679	+8.52
Orchards	5977	5974	5974	5988	6000	6000	6783	+13.49

Surce: own calculations using NIS data

The arable area of the county recorded fluctuations during the analyzed period, the lowest value (255502 ha) being registered in 2010 when the minimum period of analysis was established (*figure 1).*

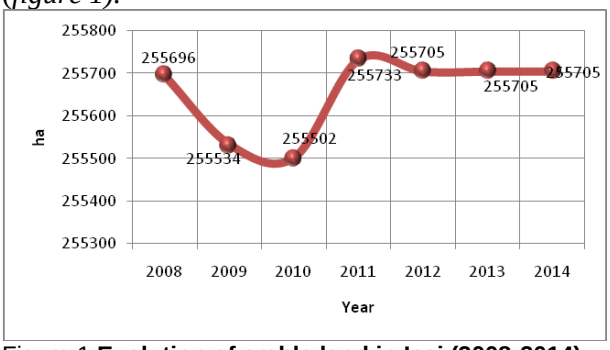

Figure 1 **Evolution of arable land in Iasi (2008-2014)**

The area cultivated in Iași County decreased from 228237 ha in 2011 to 227820 ha in 2017, the area cultivated with grain cereals declining by 4.6% - from 141569 ha in December 2011 to 134990 ha in December 2017, the yield recording fluctuations caused mainly by the climatic conditions specific to each year *(table 2*)

In 2017, the structure of the cultivated area highlights the high percentage of maize-covered areas (40.01%) and the relatively low percentage of wheat and rye-cultivated areas (15%). Sunflower culture accounts for a total of 11.4% (*figure 2*).

Table 2

Area cultivated with the main crops in Iasi (ha)

Item	2011	2012	2013	2014	2015	2016	2017	2017/ 2011 (%)
Cultivated land- total	228237	223118	222679	240322	238456	239394	227820	-0.18
Cereal grains	141569	141484	135398	146929	144063	148735	134990	-4.65
Wheat and rye	29183	31894	32294	38693	37908	38697	34142	+16.99
Barley	3445	3201	3461	4431	3804	3912	4310	+25.11
Maize	103415	100771	93946	98445	96869	100483	91165	-11.85
Oil plants	40505	34917	34807	41072	41522	36832	42781	+5.62
Sunflower	27812	27234	27055	26259	26633	25755	26180	-5.87
Sugar beet	1702	2709	2588	3476	3751	3701	3640	+113.87
Potatoes	9430	8852	8934	8501	8393	8705	5221	-44.63
Vegetables	11511	11348	11349	10572	10366	10167	10362	-9.98

Surce: own calculations using NIS data

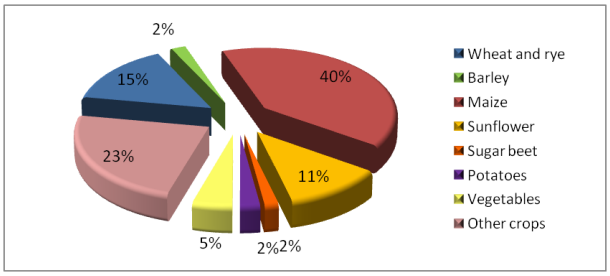

Figure 2 - ***Structure of area cultivated with the main crops in Iasi county (%)***

From a quantitative point of view, grain production grew significantly in 2017 compared to 2011 (around 30%), but potato production declined considerably (by 45%) (*table 3*).

Table 3

Vegetal production for major crops in Iaşsi county (2011-2017) (tonnes)

Item	2011	2012	2013	2014	2015	2016	2017	2017/ 2011 (%)
Cereal grains	509882	225574	523839	616617	414476	529415	664575	30.34
Wheat and rye	90390	71415	98832	122738	114068	139651	150083	66.04
Barley	10330	6623	8971	11976	9270	12352	16065	55.52
Maize	399610	137765	403905	470541	279856	365201	486253	21.68
Sunflower	48490	29362	54389	51091	44005	40398	67889	40.01
Sugar beet	50629	65519	93324	121985	134996	113555	131086	158.91
Potatoes	153054	75999	153027	141673	106819	90805	83839	-45.22

Surce: own calculations using NIS data

In the application of linear programming for the crop structure optimizing, they were considered as restrictions:

- the maximum area cultivated with the main crops;
- the minimum area cultivated with the main crops;
- the yield.

The objective functions defined in order to achieve optimization were to minimize spending and maximize profits. In determining the surface restrictions, a percentage of crops recommended in a crop rotation was taken into account, as follows: cereals - 40-60%; sunflower - 15-20%; rape - 3-7%; leguminous / potato- 15-25%. The matrix of the economic-mathematic model for optimizing the crop structure is thus presented (*table 4*).

Table 4

The matrix of economic-mathematical in linear programming model for optimizing crop structure in Iasi county

Restrictiile	Wheat+rye +triticale	Wheat for seed	Barley	Maize	Maize for seed	Soyabean	Sunflower	Rape	Sugar beet	Beans	Peas	Potatoes	Sign	Value of constraint		MU
														V1	V2	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
The maximum cultivated area	1	1	1	1	1	1	1	1	1	1	1	1	=	196.525	196.525	ha
The maximum cultivated area with wheat, rye, triticale	1												≤	40.000	40.000	ha
The minimum cultivated area with wheat, rye, triticale	1												>	26.000	26.000	ha
The maximum area cultivated with wheat for seed		1											≤	4.000	4.000	ha
The minimum area cultivated with wheat for seed		1											>	2.500	2.500	ha
The maximum area cultivated with barley			1										≤	7.500	7.500	ha
The minimum area cultivated with barley			1										>	4.000	4.000	ha
The maximum area cultivated with maize				1									≤	80.000	80.000	ha
The minimum area cultivated with maize				1									>	50.000	50.000	ha
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
The yield on wheat, rye, triticale	1												=	3.500	3.500	kg/ha
The yield on wheat for seed		1											=	2.700	2.700	kg/ha
The yield on barley			1										=	4.000	4.000	kg/ha
The yield on maize				1									=	4.000	4.000	kg/ha
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
FO1 – TOTAL EXPENSES	1950	3000	1950	2500	8500	2000	2400	2500	3600	1900	1900	7600	→	MINIM	MINIM	lei/ha
FO2 – TOTAL GROS PROFIT	1235	2940	1490	980	45500	1078	544	794	650	872	2030	6800	→	MAXIM	MAXIM	lei/ha

After analyzing the climatic and economic conditions at the level of Iaşi County, the following technic-economic indicators were analyzed for grain cereal crops along with the other crops: area (ha), total production (tones), total income (thousand lei), total expenses (thousand lei), total gross profit (thousand lei).

The crops considered were: wheat + rye + triticale, wheat for seed, barley + maize grain + sorghum, maize for seed, soybean, sunflower, rape, sugar beet, beans, peas and potatoes.

As a result of the analysis of the initial situation characteristics, it can be noticed that the most profitable crop was maize, both maize for grain - a crop with a gross profit of 101505 thousand lei and maize for seed - with even greater profit - of 211666 thousand lei due to the high price The total production of wheat obtained in the initial variant was 111871 t, while the wheat crop for seed was at the county level by 4585 t.

The income obtained for total crops was of 1001173 thousand lei, highlighted by the contribution of maize crop for consumption (360448 thousand lei). The crop of rye + rye + triticale yielded a total income of 101802 thousand lei.

The total expenses recorded in the initial version were 546498 thousand lei, the grain maize crop for consumption having the largest share in these expenditures given by the fact that it owns the largest area in the total crops. The value of the expenditures for the corresponding area of 103577 ha was 258943 thousand lei.

The gross profit reported was 454675 thousand lei. From the analyzed grain cereals, the lowest level of profit was characteristic to barley (3136 thousand lei) while the wheat crop registered a profit of 39474 thousand lei.

The structure of the crops in the initial version V_0 shows the significant share of grain maize crops for consumption in the total cultivated area analyzed - 52.70%, which also determines the high percentage held by the cereal grain crop - of 73.27%.

Consumption wheat owns 16.26% of the area under analysis while seed wheat is 0.86%. Seed maize represent 2.37% of the total and 1.07% of the area is cultivated with barley. The other crops (except cereal grain crops) hold 47.30% where: sunflower 14.55% of the total, soybean 3.36%, rape 0.94%, sugar beet 1.93%, beans 0.76%, grain peas 0.35%, and potatoes 4.83% (*figure 3*).

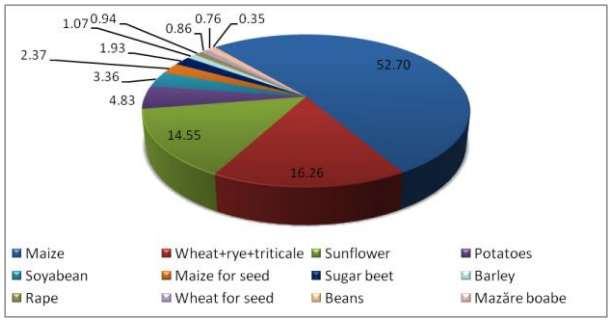

Figure 3 **The crop structure in Iași county for minimizing expenses- variant (V_0)**

After solving the economic-mathematic model, two variants were obtained: the V1 variant, which has the objective to minimize the expenses and the V_2 variant which the objective function is to maximize the profit.

The V_1 variant resulted from the mathematical modeling shows a total production of 90871 t of wheat and incomes amounting to 82692 thousand lei, while the expenditures amount to 50628 thousand lei, the gross profit being 32064 thousand lei.

For the total area taken into consideration of 196525 ha the total expenses for the crops in V_1 are 525464 thousand lei while the total gross profit is 422951 thousand lei.

For variant V_1, the following structure of crops emerged as a result of the economic mathematic model: grain cereals totaling 59.67% of which: wheat for consumption 13.21%, wheat for seed 1.37%, grain for consumption 39, 82%, maize for seed 2,16% and 3,11% barley and the other crops: 60,33% of which: 39,82%, sunflower 16,59%, soybean 4,81%, rape 4.50%, sugar beet 3.88%, bean 3.85%, pea 3.39%, and potatoes 3.31% (*figure 4*).

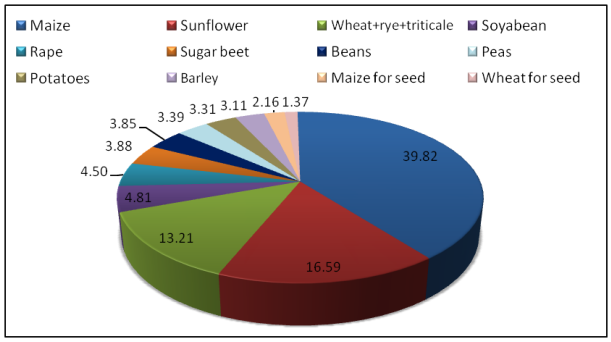

Figure 4 **The crop structure în Iași county for minimizing expenses- variant (V_1)**

In variant V_2, which has the objective of maximizing the profit it is proposed to reduce the area cultivated with cereal grains compared to the initial variant by 17.17% (from 73.27% to 56.10%). The area with wheat for consumption owns 19.83% of the total, being 3.57% larger while the crop of maize for consumption holds a

weight of 29.13% in the total cultivated area (by 23.57% lower than the V_0).

Seed crops also recorded slight surface elevations: 0.55% (from 2.37% to 3.18%) in maize and 1.02% (from 0.86% to 1.88%) for wheat. The other crops own 43.90% of the cultivated area, the largest share being held by sunflower - 16.59% of the total (by 2.04% higher than the one recorded in the original version) (figure 5).

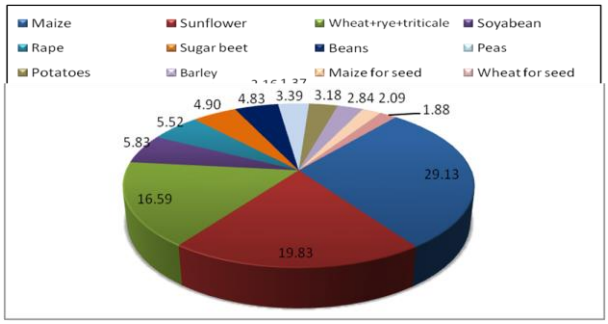

Figure 5 **The crop structure în Iași county for maximizing the profit - variant (V_2)**

In V_2 variant there are significant differences compared to V_1. Thus the weight of the total area occupied with grain cereals in total is reduced by 3.57%, but the area with wheat for consumption is 19.83% compared to 13.21% in variant V_1. Also, the seed wheat occupies an area of 1.88% of the total crops, 0.51% higher than that the percentage recorded in V_1 and the share of maize crop for consumption is significantly lower (by 10.69%).

Gross profit for wheat was in variant V_2 of 48119 thousand lei while in variant V_1 was 32064 thousand lei, the total production being 136371 t (by 21.90% higher) (fig. 6.6).

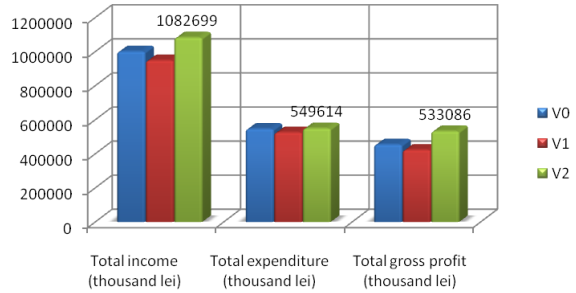

Figure 6 **Comparative analyze of income, expenses and profit in the three variants analyzed (V_0, V_1 and V_2)**

Of the two proposed optimization variants it is recommended the variant whose objective function is to maximize the profit - V_2, since, observing the conditions of a correct crop rotation and the restrictions imposed in the economic-mathematic model, a maximum profit can be achieved, with the maximum area cultivated with wheat for consumption, rye and triticale, in order to ensure the economic efficiency.

CONCLUSIONS

Linear programming is a useful method for achieving an optimal crop structure for an agricultural holding or a territorial administrative unit, and the results obtained can be implemented by the managers of the agricultural units or by the policy-makers of each region in order to ensure economic efficiency.

Selecting the optimal variant in the example of Iaşi County (V_2) allows a proper management of the agricultural land as well as ensuring the population with the necessary agricultural products in the required quantities.

Achieving a maximum profit or minimal expenditure should be the objectives of a good management and managers can use with confidence linear programming method to reach these objectives.

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