Linear Programming in Agriculture:

Case Study in Region of Development South-Mountenia

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ABSTRACT

In agriculture, the production structure of farms can be highly diversified to reduce risk and uncertainty related to unsealing the products. To determine the optimal structure of crops, different methods which take into account the income and expenditure of crops per hectare are used. As a result, the area of each crop is identified, so that, in combining them to derive maximum profit level. In this paper, linear programming method is used for optimizing profit, investigating whether, after applying the econometric model, the profit increased or not. The results show that profit rose to 143% and costs reduced to 81%.

Keywords: *Agriculture, Econometric Model, Linear Programming, Profit, Structure of Production*

INTRODUCTION

The paper investigates the economical activity of a vegetal farm and to optimize its profit using linear programming method. The research question is whether after applying the econometric model the returns of the economical activity is higher or not.

Optimizing crops' structure using linear programming is widely applied in economical research. As it is all known, in literature linear programming (Kantorovich, 1987; Dantzig, 1963; von Neumann, 1954) as a specific methodology was developed by Leonid Kantorovich, a Russian mathematician who developed linear programming problems in 1939, George B. Dantzig, who published the simplex method in 1947, and John von Neumann, who developed the theory of the duality.

The work of Dantzig (1963) is recognised to be the most applicable. His original example of finding the best assignment of 70 people to 70 jobs exemplifies the usefulness of linear programming. With the help of computers, it takes only a moment to find the optimum solution by posing the problem as a linear program and applying the Simplex algorithm. The theory behind linear programming drastically reduces

DOI: 10.4018/ijsem.2012010105

the number of possible optimal solutions that must be checked.

Nowadays, many changes have transformed the landscape of optimization methods and software since Dantzig, because of the Internet and the World Wide Web facilities. Gill et al. (2008) considers that it is no longer necessary for the critical mass of people to be co-located, since researchers and users can exchange code electronically as well as run problems on a machine in a remote location using software written by someone else. Even so, Dantzig's concept of a systems optimization laboratory lives on.

Linear programming is used in all fields, including agriculture. Montazemi and Wright (1982) applied mathematical programming in agriculture, as an example of the use of operational research in developing countries. Researchers (Voicu et al., 2010; Dobre et al., 2011; Istudor et al., 2007) show the Romanian contribution to the field.

This paper is a practical approach to the method of linear programming. The relevance of outcomes consists in the opportunity of using this methodology for maximizing profits of farms, by changing the structure of crops.

Material and Method

To optimize farm profits, the linear programming method to data supplied by a farmer has been applied. Linear programming is a mathematical method for determining a way to achieve the best outcome (maximum profit or lowest cost) in a given mathematical model for some list of requirements represented as linear relationships. Linear programming is a specific case of mathematical programming. More formally, linear programming is a technique for the optimization of a linear objective function, subject to linear equality and linear inequality constraints.

The econometric model maximizes the profit function and it is expressed by the following relationship:

$$\max.\ f(x) = \sum p_j x_j \ , j=1, 2, \ldots, n$$

The model constrains are:

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

2. $x_j \geq 0$

Of which:

x_j – area of crop j
p_j – profit of crop j
a_{ij} – resource consumption per unit of production for crop j;
bi – the volume of resources;
j – set of crops;
i – volume of crops.

Data have been collected from a farm whose object of activity is complex, containing numerous branches (crops), planted within ecological system. A diversified business structure has the advantage of reducing the effects of risk and uncertainty, but it cannot be overlooked the pronounced fragmentation of the area cultivated.

1. PHYSICAL RESOURCES OF THE FARM

1.1. Land Resources

The farm has an area larger than what is, on average, a unit of the Romanian agriculture conditions and fall in the average size of farms found in the EU area. Most of the agricultural area (93.6%) is arable land, since the holding is found in the lowlands. The plot is characterized, given its location, a good fertility, both field crops and vegetables are favourable (Table 1).

1.2. Technical Facilities

In such a physical dimension of the farm, it is natural that the technical endowment to be proportionate to the volume of working, especially if the farm doesn't provide services to other farms. Land load per tractor is 47 hectares. The existing technical facilities (Table 2)

Table 1. Land use

Specification	Total hectares	Of which:		% arable of agricultural
		Ownership	Leased	
Agricultural area, of which:	47	37	10	-
- arable	44	-	-	93.6

Table 2. The technical facilities owned by the farm

Type	2009
- Tractor U650	1
- Plows	1
- Harrow	1
- Drills	1
- Trailer	1
The agricultural area per tractor is 47 ha.	

enable the execution of the basic work of soil and crop sowing.

2. STRUCTURE OF PRODUCTION

In the structure of production (Table 3), large shares have oilseed crops (36.3%), followed by cereals (35%) and vegetables (19%). Sunflower accounts for 27% of the total area cultivated, which means the farm specialisation in oilseed crops.

3. ECONOMICAL RESULTS

Economic results achieved by the farm depend on the average yields of crops (Table 4) and the level of expenditure per unit of product and prices at which products are sold (Table 5).

Wheat, corn, cabbage, peas and lucerne productions are over the average productions at national level. Sunflower, rape, tomatoes, green-pepper, dry onion, and melons productions are below the average production at national level.

Because crops are planted in ecological systems, yields are expected to be low. But selling prices indicate high level; as a result the activity is profitable. Rape, green-pepper, peas, and dry onion have high prices (Table 5).

In a synthetic approach, all products have positive returns (Table 5). The level of profitability varies; the vegetables (green pepper, cabbage, dry onion, tomatoes) and rape have the highest levels of profits.

Based on data showing the areas cultivated (Table 3), yields (Table 4), profits and costs per tone (Table 5), profits and costs per hectare are estimated (Table 6).

Vegetables: tomatoes (3200 lei/ha), cabbage (2000 lei/ha), melons (1920 lei/ha), green pepper (1200 lei/ha), dry onion (1000 lei/ha), but also Lucerne (1100 lei/ha) have the highest levels of profits per hectare. The lucerne is harvested many times per year from the same area. Crops less intensive – wheat, sunflower, corn, rape – have lower profits per hectare.

Costs per hectare vary, also, in accordance to the level of how intensive the crops are. The most intensive: cabbage, peas, dries onion, melons indicate costs over 10000 lei/ha. The

Table 3. Crops' structure

Specification	Area cultivated (ha)	Weight of cultivated area in total area (%)
Total cereals, of which:	**16**	35.0
Wheat	8	17.0
Corn	8	17.0
Total oilseed crops, of which:	**17**	36.3
Sunflower	13	27.7
Rape	4	8.6
Vegetables and melons total, of which:	**9**	19.1
- tomatoes	0,5	1.1
- green peppers	0,5	1.1
- cabbage	0,5	1.1
- peas	1	2.1
- dry onion	1,5	3.2
- melons	5	10.6
Fodder, of which:	**5**	10.6
Lucerne	5	10.6
Total	**47**	**100**

Table 4. Crops' yields

Specification	Yields (tones/ha)
Total cereals, of which:	-
Wheat	3.15
Corn	3.6
Total oilseed crops, of which:	-
Sunflower	1.3
Rape	0.75
Vegetables and melons total, of which:	-
- tomatoes	8
- green peppers	2
- cabbage	20
- peas	3
- dry onion	5
- melons	12
Fodder, of which:	-
Lucerne	11

Table 5. Costs, prices and products' returns

Specification	MU	2009
Wheat: sold quantity	t	25.2
- cost	lei/t	300
- price	lei/t	315
- profit or loss	lei/t	15
Corn: sold quantity	t	28.8
- cost	lei/t	330
- price	lei/t	360
- profit or loss	lei/t	30
Sunflower: sold quantity	t	16.9
- cost	lei/t	700
- price	lei/t	750
- profit or loss	lei/t	50
Rape: sold quantity	t	3
- cost	lei/t	950
- price	lei/t	1150
- profit or loss	lei/t	200
Tomatoes: sold quantity	t	4
- cost	lei/t	800
- price	lei/t	1200
- profit or loss	lei/t	400
Green peppers: sold quantity	t	1
- cost	lei/t	1900
- price	lei/t	2500
- profit or loss	lei/t	600
Cabbage: sold quantity	t	10
- cost	lei/t	1100
- price	lei/t	1200
- profit or loss	lei/t	100
Peas: sold quantity	t	3
- cost	lei/t	3800
- price	lei/t	4000
- profit or loss	lei/t	200
Melons: sold quantity	t	60
- cost	lei/t	1040

continued on the following page

Table 5. continued

- price	lei/t	1200
- profit or loss	lei/t	160
Dry onions: sold quantity	t	7.5
- cost	lei/t	3500
- price	lei/t	3800
- profit or loss	lei/t	200
Lucerne: sold quantity	t	55
- cost	lei/t	1000
- price	lei/t	1100
- profit or loss	lei/t	100

less intensive: wheat, corn, sunflower, and rape indicate costs at around 1000 lei/ha.

4. SWOT ANALYSIS OF THE FARM ACTIVITY

Carrying out the SWOT analysis, for this research, the following aspects arises

A. Strengths

- Farm production is certified as organic;
- The surface is above what is used for family farms and in general on average in romania;
- The production structure is diversified, which can be viewed as a means of reducing the effects of risk and uncertainty related to the capitalization of agricultural products;
- The level of equipment availability for caring out the basic land work and sowing is high, and the level of the land area per one tractor is over its level in EU;
- Only organic fertilizers are used (manure);
- Farming is profitable (but it has as source the subsidies as well).

B. Weaknesses

- Reduced average yields for some crops, and, as a results, reduced output, income and, finally, financial results;
- One-man decisions, given the existence of a single administrator. This may reveal problems in underpinning decisions;
- Increased diversification of production structure, which, apart from its advantages, generates negative effects due to dispersal areas and efforts.

C. Opportunities

- Increasing demand for farm's products as a result of consumer attitudes towards organic products, including their higher prices;
- A more consistent policy to support producers who practice organic farming;
- Increasing interests of beneficiaries as a result of obtaining production in organic system.

D. Threats

- Extension of economic crisis;
- The decrease in sales prices as a result of reduced purchasing power of members of society;
- Increasing prices of inputs;
- Increasing competition from other competitors who produce in organic system, including imported products.

Table 6. Profits and costs per hectare

Specification	Profit (lei/ha)	Costs (lei/ha)
Total cereals, of which:	-	-
Wheat	47.25	945
Corn	108	1188
Total oilseed crops, of which:	-	-
Sunflower	65	910
Rape	150	712,5
Vegetables and melons total, of which:	-	-
- tomatoes	3200	6400
- green peppers	1200	3800
- cabbage	2000	22000
- peas	600	11400
- dry onion	1000	17000
- melons	1920	12480
Fodder, of which:	-	-
Lucerne	1100	11000

Results and Discussions

The present structure of production returns to the farmer the profit:

$$P_0 = \sum_{j=1}^{11} p_j \cdot x_j = 23087 \text{ lei} \quad ,$$

Of which:

P = total profit
p_j = profit per unit of production for crop j
x_j = area of crop j

After applying the linear programming method, the crops' structure of the farm is optimized.

In a first variant, restrictions on the maximum surface are not introduced; therefore the result of implementing the program is to assign the whole area of 47 ha to the crop that has the highest profit per hectare – tomatoes. Total profit for the first variant is $P_1 = 150400$ lei.

To ensure crop rotation a set of restrictions on maximum area should be introduced for crops. The optimal surface for planting vegetables crops is 2 ha, so the limits are inserted in the linear programming model. As a result, the following values for the variables x_j and total profit and expenditure issue:

Variant 2:

$$P_2 = \sum_{j=1}^{11} p_j \cdot x_j = 34330 \text{ lei}$$

$$Ch_2 = \sum_{j=1}^{11} c_j \cdot x_j = 842656 \text{ lei}$$

With the following structure of production:

Wheat: $x_1 = 0$ ha
Corn: $x_2 = 0$ ha
Sunflower: $x_3 = 0$
Rape: $x_4 = 27$ ha
Tomatoes: $x_5 = 2$ ha

Table 7. Outcome of optimizing the structure of production (ha)

Crop	Variant 0 (current)	Variant 1	Variant 2	Variant 3
Wheat	8	0	0	5
Corn	8	0	0	7
Sunflower	13	0	0	5
Rape	4	0	27	10
Tomatoes	0,5	47	2	2
Green pepper	0,5	0	2	2
Cabbage	0,5	0	2	2
Peas	1	0	2	2
Melons	5	0	4	4
Dry onion	1,5	0	2	2
Lucerne	5	0	6	6
Total profit (lei)	*23087*	*150400*	*34330*	*33097,25*
Total expenditure (lei)	*1034000*	*300800*	*842656*	*837169*

Green pepper: $x_6 = 2$ ha
Cabbage: $x_7 = 2$ ha
Peas: $x_8 = 2$ ha
Melons: $x_9 = 4$ ha
Dry onion: $x_{10} = 2$ ha
Lucerne: $x_{11} = 6$ ha

Of which: $Ch =$ total expenditure.

The option set out, vegetable crops are restricted to maximum 2 ha, peas: 2 ha, melons: 4 ha, and lucerne to 6 ha. The remaining area is allocated to the most profitable of the culture that did not receive limits – rape. Because cereals lack of rotation, which does not permit rational rotation of crops, new limits' restrictions are inserted.

As a result, the following values for the variables x_j and total profit and expenditure issue:

Variant 3:

$$P_3 = \sum_{j=1}^{11} p_j \cdot x_j = 33097.25 \text{ lei}$$

$$Ch_3 = \sum_{j=1}^{11} c_j \cdot x_j = 837169 \text{ lei}$$

With the following structure of production:

Wheat: $x_1 = 5$ ha
Corn: $x_2 = 7$ ha
Sunflower: $x_3 = 5$
Rape: $x_4 = 10$ ha
Tomatoes: $x_5 = 2$ ha
Green pepper: $x_6 = 2$ ha
Cabbage: $x_7 = 2$ ha
Peas: $x_8 = 2$ ha
Melons: $x_9 = 4$ ha
Dry onion: $x_{10} = 2$ ha
Lucerne: $x_{11} = 6$ ha

In Table 7, the outcomes of applying linear programming method are centralized.

Compared to the initial scenario, in the other variants the profit increases. In version 1, the profit is maxim, but the structure of production does not ensure its rotation. Option 3 is the optimal structure of production because, although reporting a lower profit than in version 2, however, areas occupied by intensive crops - vegetables, beans, melons – are in balance with extensive crops. In addition, grains, oilseeds and lucerne, for which the farmer has the technical facilities needed to carry out the work, occupy 70% of the total area, and vegetables, for which work is done largely by hand, occupies 30%. It is both about a better allocation of production factors and about maximizing profits.

CONCLUSION

The economic activity of the farm which provided the economic data is more profitable after optimizing the structure of production. The profit increased to 143% and costs reduced to 81%. Production structure is optimized using linear programming method; all crops are maintained into production, ensuring thus their rotation and as a result, increased yields. The results have practical applicability; farmers may underpin scientifically their decisions of resource allocation: land (production structure), materials and money.

REFERENCES

Dantzig, G. (1963). *Linear programming and extensions*. Princeton, NJ: Princeton University Press and the RAND Corporation.

Dobre, I., Voicu, R., & Bran, M. (2011). The phenomenon of diversifying in production structure and its impact economic, social and ecologic. *Journal Quality – Access to Success, 12*(121), 171-175.

Gill, Ph., Murray, W., Saunders, M., Tomlin, J., & Wright, M. (2008). George B. Dantzig and systems optimization. *Discrete Optimization*, *5*(2), 151–158. doi:10.1016/j.disopt.2007.01.002

Istudor, N., Manole, V., Ion Raluca, A., & Pîrjol, T. (2007). Mathematical model for optimizing the profit of the pork meat chain. *Journal of Applied Quantitative Methods*, *2*(4), 506–516.

Kantorovich, L. V. (1987). My journey in science (proposed report to the Moscow Mathematical Society). *Russian Mathematical Surveys*, *42*(2), 233–270. doi:10.1070/RM1987v042n02ABEH001311

Montazemi, M., & Wright, D. (1982). Mathematical programming in subsistence agriculture. *European Journal of Operational Research*, *10*(4), 346–350. doi:10.1016/0377-2217(82)90085-6

Turek, A. (2008). *Îmbunătăţirea managementului structurilor de producţie din regiunea de dezvoltare Sud-Muntenia în scopul creşterii competitivităţii exploataţiilor agricole* (PNII Contract No. 52126/2008). Retrieved from http://www.cnmp.ro:8083/pncdi2/program4/documente/2010/sedinta/rez/D5/52-126.pdf

Voicu, R., Rahoveanu, T. A., & Ion Raluca, A. (2010). The structure of production in Romanian agriculture - the gap between the EU 27. *Economics of Agriculture*, *2*, 366–374.

von Neumann, J. (1954). A numerical method to determine optimum strategy. *Naval Research Logistics Quarterly*, *1*(2), 109–115. doi:10.1002/nav.3800010207

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