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ECONOMIC EFFECTS OF OPTIMIZATION IN FRUIT GROWING USING LINEAR PROGRAMMING

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Abstract

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During our work, we optimized raising plantations in the area of fruit growing by the method of linear programming. Optimization was performed in five fruit species, as follows: apples, pears, plums, sour cherries and cherries. Goal function is to maximize gross profit. When planting on 120 hectares, the optimal solution of the structure of plantation is as follows: 39.92 hectares of apples, 2.03 hectares of pears, 58.47 hectares of plums, 16.4 hectares of sour cherries and 1.65 hectares of cherries. Cost function for planting 117.4 hectares provides a gross profit of 30 939.8 thousand RSD, or with the correction of the planting program, 31 740 thousand RSD for 2.53 hectares. The largest gross profit is achieved by planting apples, plums and sour cherries, which is in line with the market demand.

Key words: linear programming, optimization, fruit plantations, gross profit maximization

Introduction

Raising fruit plantations on farmer households is of extreme importance for change of production structure, intensification of agricultural production and increase of economic and environmental profit while protecting environment (Babovic, 2008). The farm in question was on a 120 ha parcel. The soil was not used for production for three years. An analysis of soil structure and quality was also performed. It was decided to raise an orchard and propose an economically integral planting structure of fruit species. To this end, the task was to choose fruit species, which contribute to achieving the maximum gross profit by using quantitative methods of optimization in raising fruit plantations.

The Aim and Method of Research

The quantitative and qualitative method was used in finding the optimal solution for raising fruit plantations. The optimization of raising the fruit plantation on 120 hectares area was carried out by using linear programming.

Linear programming is one of the methods of *mathematical programming* which enables the development of a mathematical model of a task, whose solution gives the optimal plan, or from the management aspect, the most favorable way of task realization in given conditions and with given constraints. Linear programming is the most effective mathematical instrument applicable to solving a greater number of complex and multidisciplinary business problems (Vanderbei, 2000). Linear programming allows a complex review and a proper evaluation of significance of many factors that need to be taken into account. Hence, the application of linear programming in the field of agricultural production management, where such multi-dimensional issues are being studied. *Linear programming provides a model for the problems of conditional optimization* and enables finding the optimal solution, or a solution that provides the best value of the preferred target from the set of all possible or acceptable solutions, in which each solution from the given set meets conditions or limitations (Turban, 2005).

The method is represented by three crucial parts: a function of an aim, a group of limitations and a group of conditions of non-negativity. In order to solve a standard problem by using **a simplex method** of linear programming, we begin from functions of criteria for a maximum in the basis (Beneke and Winterboer, 1973).

$$(max)z_0 = c_1x_1 + c_2x_2 + \dots + c_sx_2 + \dots + c_kx_k; \quad (1)$$

by a restriction,

$$a_{11}x_1 + a_{12}x_2 + \dots + a_{1s}x_s + \dots + a_{1k}x_k \leq b_1;$$
$$a_{21}x_1 + a_{21}x_2 + \dots + a_{2s}x_s + \dots + a_{2k}x_k \leq b_2;$$

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$$\vdots$$
$$a_{m1}x_1 + a_{m1}x_2 + \dots + a_{ms}x_s + \dots + a_{mk}x_k \leq b_m$$

under a condition, $x_1, x_2 \dots x_n \geq 0$, by which s, k. m are arbitrary cardinal numbers, coefficients cij and aij are known real numbers with two marks are indexes which precisely establish their places, and a coefficient aij will make a rectangular matrix of m, x, n order. Free members B (i=1,2,m) represent a group of constants, non-negative restrictions are located on the programme, the variables of making decisions are marked with xj (j=1,2,.. n).

In order to limit ourselves to solving the problems of linear programming of a standard form, it is necessary a system of linear non-equations of restrictions to be transformed into a system of linear equations. There are included some additional variables which are also found in a function of an aim by which a function of an aim is modified. In this way, we get a model adjusted to the usage of an alogaritam of a simplex method.

The Optimization of Fruit-Growing By Using a Linear Programming

In the procedure of planning and programming of production and investments, a linear programming makes the optimal production or financial results to be found. By applying a simplex method it is defined an optimal structure of sowing-time and production in tillage, an optimal production in cattle breeding, an optimal structure of planting and economic effects in fruit-growing and the other things. The programme enables the optimization of planting structures and production results in fruit-growing on the land of 120 ha (Radović, 2002; Babovic, 2009). This programme can be applied or recalculated to any planting area. In the programme we start from the market demand, customers` requests and built warehousing capacities.

The programme covers fruit species, variables of making decisions: an apple x1, a pear x2, a plum x3, a sour cherry x4 and a cherry x5. A function of an aim includes a maximal profit, and coefficients from c1 to c5 mark the prices according to variables of making decisions. A following relation can show the function:

$$(\max)\ z_0 = c_1 x_1 + c_2 x_{2} + c_3 x_3 + c_4 x_4 + c_5 x \qquad (2)$$

Production results of fruit planting areas are represented in a Table 1.

In a simplex method, we take the following conditions of restrictions, which will, besides production, investment and financial results, decide about a choice of an optimal structure of planting area of 120 hectares.

The first condition- a restriction of planting area of 120 ha, and it can be a smaller one, if other restrictions would be within the limit of utilization, which refers to annual expenses and investments. We transform a condition into a linear non-equation (Babovic, 2009):

$$1x1 + 1x2 + 1x3 + 1x4 + 1x5 < 120 \qquad (3)$$

The second condition refers to a disposable working capital of 46,2 million of dinars. According to the previous table this condition can be transformed into a non-equation:

$$630x1 + 320x2 + 280x3 + 250x4 + 230x5 < 46.2 \qquad (4)$$

The third condition refers to a disposable labour of 26 000 hours in May. An apple demands 80 hours, a pear 105 hours, a plum 135 hours, a sour cherry 840 hours and a cherry 600 hours per a hectare. The condition is transformed into a linear equation:

$$80x1 + 105x2 + 135x3 + 840x4 + 600x5 < 26\,000 \qquad (5)$$

The fourth condition refers to a disposable labour of 19 000 hours at the time of fruit-picking in October when an apple demands 440 hours, a pear 800 hours, a plum 3 hours, a sour cherry 2 hours and a cherry 3 hours per a hectare. We transform the condition into a linear non-equation:

$$440x1 + 800x2 + 3x3 + 2x4 + 3x5 < 19\,000 \qquad (6)$$

Table 1
Production results of fruit planting areas

Code	A fruit species	Yield	Value	VT	Gross profit	Investments
x_1	An apple	40	1.000	630	370	680
x_2	A pear	30	640	320	320	500
x_3	A plum	20	400	120	120	320
x_4	A sour cherry	18	550	300	300	350
x_5	A cherry	16	500	270	270	310

The fifth condition refers to disposable working hours of the middle-sized tractors of 530 hours in May when an apple demands 5 hours, a pear 3 hours, a plum 2 hours, a sour cherry 11 hours and a cherry 8 hours per a hectare. The condition is transformed into a linear non-equation:

5x1 + 3x2 + 2x3 + 11x4 + 8x5 < 530 (7)

The sixth condition refers to a demand of tractors of 830 hours in October. An apple demands 15 hours, a pear 6 hours, a plum 3 hours, a sour cherry 2 hours and a cherry 3 hours. This condition can be transformed into a linear non-equation:

15x1 + 6x2 + 3x3 + 2x4 + 3x5 < 830 (8)

The seventh condition refers to the fact that we demand a maximum of 3 500 t of production from the programme. According to the table, we can illustrate a following non-equation:

40x1 + 30x2 + 20x3 + 18x4 + 16x5 < 3 500 (9)

The eighth condition was included when an apple and pear did not allow a sour cherry and cherry to be involved in the programme because of greater effects, because of which the planting areas of apples, pears and plums were restricted to 100 hectares. This can be transformed into the following linear non-equation:

1x1 + 1x2 + 1x3 < 100 (10)

The ninth condition refers to disposable investments of 52.5 million of dinars. An apple demands 680 thousand of dinars, a pear 500 thousand of dinars, a plum 320 thousand of dinars, a sour cherry 350 thousand of dinars and a cherry 310 thousand of dinars per a hectare. The condition can be transformed into a linear non-equation:

680x1 + 500x2 + 320x3 + 350x4 + 310x5 < 52 500 (11)

A condition of non-negativity of variables of making decisions is given through a following relation:

x1, x2, x3, x4, x5 > 0 (12)

By including 9 additional variables - one for each restriction there is given a starting simplex matrix being shown in Table 2.

Table 2
The starting table of a simplex method in programming of an optimal structure of 120 hectares of planting orchards

Cs	X_3	A type of a restriction	A quantity	Basic variables					Additional variables										R
				370	320	180	300	270	0	0		0	0	0	0	0	0	0	
				X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	
0	X_6	Planting areas	120.0	1	1	1	1	1	1										
0	X_7	Direct investment expenses represented n 000 dinars	46.120	630	320	280	250	230		1									120
0	X_8	The regular labour shown in hours in May	26.000	80	105	135	840	600			1								73.20
←0	X_9	The regualr labour shown in hours in October	19.000	<u>440</u>	800	3	2	3				1							325
0	X_{10}	Middle-sized machinery- tractors shown in hours in May	530	5	3	2	11	8					1						43.18
0	X_{11}	Middle-sized machinery- tractors shown in hours in October	830	15	6	3	2	3						1					106
0	X_{12}	The range of production represented in tones	3.500	40	30	20	18	16							1				55.33
0	X_{13}	The restrictions for	100	1	1	1	-									1			87.50
0	X_{14}	The investments represented in 000 dinars	52.500	680	500	320	350	310									1		100
		Zj-Cj	0	-370	-320	-180	-300	-270	0	0	0	0	0	0	0	0	0	0	77.20
		d		↑															

Table 3
The optimal structure of fruit-growing areas of 120 hectares

Code	A fruit species	I solution		II solution	
		Ha	%	Ha	%
x_1	An apple	38.92	38.13	33.90	32.50
x_2	A pear	2.03	1.72	3.00	2.50
x_3	A plum	58.47	49.77	58.00	48.33
x_4	A sour cherry	16.40	13.36	17.00	14.7
x_5	A cherry	1.65	1.42	3.00	2.50
	Totally	117.47	100.00	120.00	100.00

Table 4
The optimal planting structure insures the financial effects (000 dinars)

	The production value		Direct expenses		Gross profit	
	per ha	Totally	per ha	Totally	per ha	Totally
An apple	1.000	39.000	630	24.570	370	14.300
A pear	640	1.920	320	960	320	960
A plum	460	26.680	280	16.400	180	10.400
A sour cherry	550	9.300	250	4.250	300	5.100
A cherry	500	1.500	230	90	270	810
Totally	-	78.400	-	46.710	-	31.740

By using a computer there have been done the second, third and forth iteration and in the fifth iteration there has been found an optimal solution of the planting structure according to an area and profit.

An optimal solution insures a maximal gross profit of 30 939.8 thousand of dinars and the optimal structure of fruit-growing areas. The optimal programme of the planting structure completely satisfies all restriction conditions although it has not included 2.53 hectares. The optimal programme of the fruit-growing planting structure is very optimal with the given restrictions being included.

The optimal structure of fruit-growing areas of 120 hectares is represented in Table 3.

The optimal planting structure insures the financial effects (000 dinars) is presented in Table 4.

It has been provided an aim function - a gross profit of 30 939.8 thousand of dinars by planting of 117.4 ha or of 31 740 thousand of dinars with a correction of the programme of 2.53 ha.

Conclusion

The optimal structure of orchard plantation on 120 hectares area was determined by using linear programming. The optimal planting structure is as follows: 38.92 ha of apples, 2.03 ha of pears, 58.47 ha of plums, 16.4 ha of sour cherries and 1.65 ha of cherries. The optimal value of production was determined in case of planting 117.4 hectares, with the profit of 78 400 thousand RSD and gross profit of 31 740 thousand RSD. From the aspect of goal function, maximum gross profit is achieved by planting apples, plums and sour cherries. The mathematical model of linear programming is applicable in selection of every size type of plantation on farmer households.

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