Using a multiperiodic linear programming model and a simulation programme for competing field crops and energy orchards

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Considering the land use of Hungary, there is a need to develop a rationale land use in which, beside the less-favoured areas, the use of set-aside areas are also permitted. There are several opportunities to utilize the less-favoured areas.

We prepared a multiperiodic linear programming model in order to model the crop structure, in which field crops with woody energy orchards were also competed. After having each field and orchard technology compiled, we set the dynamic simulation model, that we prepared in MS Excel. After running the model we analyzed the shadow prices of the constraints and the marginal cost of variables. Considering the result of the analysis and the professional information we made a sensitivity analysis, which gave a basis to create new decision variants. The results of linear programming model were compared with those of Monte Cralo simulation's, where we managed the enterprises' profit contribution as probability variable with normal distribution in the course of modelling.

Keywords: simulation, linear programming, rational land use, biomass

1. Introduction

The aim of this research work is the analysis of the joint applicability of a multiperiodic linear programming model – *LP model* – and the *Monte Carlo* simulation. We used the analysis to plan the medium-term (6 years) crop structure of biomass products for energy purposes.

Reviewing the domestic land use, in the past 80 years there has been significant changes. The rate of forest and set-aside areas has been constantly increasing from 1950, and the rate of arable lands that are registered as non-cropped or waste land year by year are also significant.

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Within the utilization of fields we must differentiate the *food production* and the *energy production*. Since food production must be always treated with fundamental significance, therefore this production objective must override the others.

As far as choosing the type of agricultural production is concerned, it is important to analyze that on those fields, where for the producer cannot or can only hard put up the money for the production costs, gainfully sustainable – with less material and energy expenditure - production types have to come to the front. This must be connected with the determination that such a system should not be established and operated that goes with more greenhouse gas emission than the previous systems.

On those agricultural lands, where economic production cannot be executed one possible land use method is *to plant energy orchards*. This is also backed by a study published by the Agricultural Economics Research Institute, that is to say that besides the production of major field crops - mostly cereals and oilseeds – it is important to produce energy crops if we see the bioenergy-production's increased need for raw materials (Udovecz et al. 2007).

In many agricultural studies (Erdős – Klenczner 2000, Gergely 2000a, Gergely 2000b, Erdős 2007) can be read that the agricultural strategy does not deal with sufficient energy orchards as an option for *alternative land use*. One reason for this that producers would not want to adopt orchard planting requiring major employment – compared to crop cultures – on lower quality, less-favoured areas and fields being in the red. The other reason is that the majority of producers see the tasks of agriculture in food production, the result and the income cannot be demonstrated yearly, and because of lack of information farmers are averse from wood production.

The most frequent plants of *energy orchards with short cutting-cycle*, which are grown on fields, are locust, poplar and willow. Under intensive production circumstances all three species can produce high yields; however, they are very sensitive for the endowment of the production site. The average lifespan is about 20 years with harvest in every 1-3 years. They are suitable to reach dependably high yields (8-30 tons/ha) under proper site conditions (Table 1.).

Table 1. Yields and characteristic data of woody energy plants in Hungary

Wood species	**Energy content MJ/kg**	**Average yield kg/ha/year**	**Moisture content %**	**Cutting cycle year**	**Lifespan year**
Locust	14,8	7900	15	3	20
Poplar	15,1	20000	15	2	20
Willow	14,8	30000	15	1- 3	25

Source: Marosvölgyi (1998), Führer et al. (2003), Bai (1999), Bai et al. (2002), Defra (a), Gergely (1988)

Beside woody energy orchards, herbaceous plants are of also great significance, from which hemp, Chinese reed and various energy grasses are being dealt with in Hungary. The yield and energy content to be expected are shown in Table 2.

Table 2. Yields and characteristic data of herbaceous energy plants in Hungary

Plant	Energy content MJ/kg	Average yield kg/ha/year	Moisture content %	Cutting cycle year	Lifespan year
Energy grass	15,0	13000	15	1	15
Chinese reed	13,0	17000	15	1	15
Hemp	15,7	12500	10	1	1

Source: Janowszky (2002), Iványi (2001)

Within the energy production cereals, corn, rape and various agricultural by-products will be of greater significance. Yield and energy content data are shown in Table 3.

Table 3. Yield and characteristic data of some field crops in Hungary

Plant	Energy content MJ/kg	Average yield kg/ha/year	Moisture content %	Cutting cycle year	Lifespan year
Cereal grains	14,0	7000	15	1	1
Cereal straw	14,3	6000	15	1	1
Whole cereal	14,1	13000	15	1	1
Rape	14,2	3500	15	1	1

Source: Hartmann-Kaltschmidt (2002)

2. Methodology of modelling

2.1. Short introduction of the applied linear programming model

We made a multiperiodic linear programming model for modelling the production structure, in which we competed the wheat, corn, turnsole and winter colza among field crops, and among woody energy plants locust, poplar and Swedish willow. This is a dynamic simultaneous model that we made by *Microsoft Excel* and the details of technological matrix for each year is in the diagonal of the table. The breakdown of the technology is made by months. The time interval is 6 years that was chosen because of the energy orchards' specific characteristics. Since the linear programming model contains *60 variables* and *160 constraints*, thus this model can be only presented in the annex of this study. The variables of the model were given for the planned area under cultivation, planned amount of intermittent labour in shift hours, for the given machine types, and for the number of leased shift hours. The constraints for each year are provided for the area, for machinery work, for leased machinery work, for the available labour force and leased labour force.

In the model we assume that the area of the planted woody energy plants in the beginning of the 6-year-period remains unchanged:

$$x_j^k = x_j^{k+1} \text{ thus}$$

$$x_j^k - x_j^{k+1} = 0$$

k=1,2,…6 : the ordinal number of the actual year

The above variables connect each year together, so these can be named as transfer variables. It was necessary, because in case of orchards the size of the area in the first year has to be run through the period of 6 years.

We look for the *maximum profit contribution* in the model for the whole period – which is now 6 years.

$$\sum_{j=1}^{n} \sum_{k=1}^{6} (T_j^k - C_j^{k\,\text{variable}}) x_j^k - \sum_{k=1}^{6} C_i^{hk} \delta_i^{hk} \Rightarrow \max!$$

T_j^k : Production value of the j[nth] enterprise in the k[nth] year;

$C_j^{k\,\text{variable}}$: Variable cost of the j[nth] enterprise in the k[nth] year;

x_j^k : Size of the j[nth] enterprise in the k[nth] year;

C_i^{hk} : Additional cost of the h[nth] machine compared to the own resource in the k[nth] year;

δ_i^{hk} : Number of leased hours for the i[nth] period in the k[nth] year from the h[nth] resource for lease work.

In case of field cultures we built into the model a rate of 4% income change between each year. For orchards the profit contribution of each year changed according to the harvest of the cultures. We calculated with 3 years cutting cycle in case of locust and Swedish willow and with 2 years for poplar.

2.2. Theoretical background of the simulation model

The simulation model is such a simplified mathematical implementation of a real system that studies the behaviour of the original system under changing different conditions, circumstances. In spite of the accurate results provided by analytical models, the simulation process involves the model's run over time and execution to provide representative samples about performance indicators describing the operation of the system (Winston 1997). *Stochastic* and *deterministic models* are differentiated. Randomness is not built into the deterministic models (Kovács et al. 2007a). The gist of stochastic simulation is that we choose values randomly according to the probability distribution assigned to individual uncertain factors that are used in the experiments of the simulation analysis. (Russel-Taylor 1998). In the model to be analysed we set the influence variables and their possible intervals, their probability distributions and the relationship among the variables. The given interval and distribution values of variables are formed by random number generator. The model is run several times in a row, generally *1000-10000 times* and thus we get an expected value and a variance range for the result variable to be determined. By the distribution function the probability can be determined that the value of the given variable will be in the given interval (Kovács et al. 2007b). Most recently income is given as a result variable in the models and the risk is observed at which probability it will be above the value or below. By increasing the number of runs the distribution of the result variable can be given by arbitrary accuracy (Watson 1981, Jorgensen 2000):

$$\psi = E_\pi\{U(X)\} = \int U(x)\pi(x)dx \text{ , where}$$

$X = \{\theta, \phi\}$ means vectors containing θ decision parameters and ϕ state parameters, and π means x distribution. U(x) is a utility function which means usually the income, Eπ () function gives the expected utility by given distribution.

The advantage of the method is that the model is run for decision variants individually as well, and the risk of different decision variants can be compared. The following formula is applied for the numerical determination of their integral value (Jorgensen 2000):

$$\overline{\psi} = \frac{1}{k}\{U(x^{(1)}) + ... + U(x^{(k)})\}\text{, where}$$

k means the number of experiments, i.e. the number of runs.

Excellent, easily manageable simulation softwares can be used, for example *Crystal Ball* (Decisioneering, Inc.) and @Risk (Palisade Corporation). These are based on the well-known Excel spreadsheet programme. The model to be applied will be set up here, which parameters can also be stochastic. The parameters' distribution can be chosen from several distribution types. After the running, the simulation gives the distribution of the result variable, by which it can be stated that at which probability the examined variable will take its value in a given interval.

In the course of our research we applied the Crystal Ball programme package. By this programme we had the opportunity to find the *marginal value of the objective function* and to give the constraints of the resources within the optimal crop structure.

3. Database of the analysis

The database of the analysis is given by Szabolcs-Szatmár-Bereg County, which is located in the north-eastern part of Hungary, amounting 6,4 percent of the national territory. It is the sixth largest county of the country. The area borders on three countries – Romania on the east, Ukraine on the north-east and Slovakia on the north.

Considering the geographic endowments, the following regions belong to this county: the very eastern part of the Great Plain, 78 percent of Nyírség, among the small areas of upper Tisa the whole Rétköz, the flats of Szatmár and Bereg, and the western part of the wetland of Ecsed.

The characteristic climate of this county is continental with the annual mean temperature between 9,0-9,5°C. The annual precipitation was about 400-550 millimetres according to the means of the latest years. The winter is colder and longer usually compared to the Great Plain.

The water requirements of the county are given by mostly artesian water and less by rivers. Its largest river is the Tisa that enters the country at Tiszabecs. Other major watercourses are Szamos, Túr, Kraszna and Lónyai sewer.

In agricultural terms of the county, the acreage is 623.000 hectares, from which 82 percent is production area. Within crop production cereals have a significant role, since compared to the national data 8,6 percent of corn, 25 percent of rye, 8,5 percent of potato, 9,2 percent of turnsole and 80 percent of tobacco are produced in this county. Nationally the production of cabbage, sweet corn, tomato, water melon and cucumber is of definite value.

In the county fruit production is done on 33.000 hectares, which means 34 percent of the country's territory. More than 50 percent of the national produce is yielded in this county. Apple has been of great significance for decades.

Considering forest management, 105.000 hectares from the county's territory are dealt with forest, from which locust and noble poplar are of great significance. These give 47 and 22 percent of all wood types in the county.

The database of our research work was given by a holding of this county with average natural endowments. When we set up the model we used the applied technology of this holding. The holding manages 500 hectares, so we took this also into consideration. In our analysis we dealt with corn, wheat, winter colza, turnsole, locust, poplar and willow among the crops of alternative crop production.

4. Cost and income calculation

We competed each enterprise according to their profit contribution value in our model. Profit contribution was calculated by the difference of production value and variable costs. The choice of this income category was necessary, because our aim was the *income maximalisation*.

For the calculation of production value we took into account the turnover, the financial assistances and other incomes as well. Raw data for the income was calculated when drafting the enterprise technologies, which is calculated by the multiplication of yield values per hectares and marketing prices. We considered the support levels by the actual laws, and the contractual and estimated prices for the marketing. The financial assistance has two parts: Single Area Payment Scheme (SAPS) and the national envelope Top-up. Among the crop enterprises of the holding we calculated with these two payments for all arable and energy crops.

We took into account the variable costs in case of doing the *enterprises'cost calculation*. We calculated with material costs, labour costs, machinery costs and other direct costs as well. Material costs are the cost of seeds, cuttings' costs, cost of fertilizer and pesticides. Labour costs could be assigned to each enterprise. Special attention was given to the costs of fuel, upkeep and repair as the costs of machinery.

The determination of *profit contribution* was done after the calculation of incomes and costs. Corn had the highest value among arable crops, approximately 143.000 Ft/hectares. Among the examined crops, wheat (128.000 Ft) and winter colza (125.000 Ft) were the second, and after that the turnsole (87.000 Ft) (Table 4.).

Table 4. Profit contribution value of arable crops for one hectare in the examined years

Plant	PC Ft/ha
Year 1	
Corn	147 811
Turnsole	87 906
Winter wheat	128 026
Winter colza	125 147
Year 2	
Corn	149 289
Turnsole	88 785
Winter wheat	129 306
Winter colza	126 398
Year 3	
Corn	150 782
Turnsole	89 673
Winter wheat	130 599
Winter colza	127 662

Plant	PC Ft/ha
Year 4	
Corn	152 290
Turnsole	90 570
Winter wheat	131 905
Winter colza	128 939
Year 5	
Corn	153 813
Turnsole	91 475
Winter wheat	133 224
Winter colza	130 228
Year 6	
Corn	155 351
Turnsole	92 390
Winter wheat	134 557
Winter colza	131 531

Source: own creation

After having determined the value of the profit contribution for the first year, we calculated with a *5 percent of income increase and a 4 percent of cost increase*. The base of the given annual profit contribution is given by the income and cost data of the previous year.

In the course of defining the profit contribution of energy orchards we must take into consideration that *harvesting* does not happen in every year. In case of energy orchards in the years when harvesting is done the profit contribution will be positive, in every other cases we calculate with negative values. Of course, there are exceptions as well. Since we calculated with the amount of assistance also in every year, thus there were some years when we got positive profit contribution. The harvesting cycle for locust and willow is 3 years, in the case of poplar it is 2 years.

The profit contribution values of energy orchards are shown in Table 5. As for the arable crops as well, after having determined the value of the profit contribution for the first year, we calculated with a *5 percent of income increase and a 4 percent of cost increase*. The base of the given annual profit contribution is given by the income and cost data of the previous year.

Table 5. Profit contribution value of energy orchards for one hectare in the examined years

Wood species	PC Ft/ha	Wood species	PC Ft/ha
Year 1		**Year 4**	
Locust	-505 335	**Locust**	-157 188
Poplar	-423 674	**Poplar**	232 401
Willow	-531 170	**Willow**	-149 911
Year 2		**Year 5**	
Locust	672	**Locust**	24 745
Poplar	134 224	**Poplar**	-179 151
Willow	-2 154	**Willow**	24 745
Year 3		**Year 6**	
Locust	356 525	**Locust**	403 243
Poplar	-182 789	**Poplar**	232 401
Willow	503 738	**Willow**	604 233

Source: own creation

5. Evaluation of the results

5.1. The evaluation of the basic model made by linear programming

In the course of our calculations we made a multiperiodic linear programming model, in which we competed among the arable crops the wheat, the corn, the turnsole and winter colza, whereas among woody energy orchards the locust, the poplar and the Swedish willow. The model was made in MS Excel.

We set up the basic model (*LP_BASIC*) according to the initial profit contributions (Table 4. and 5.), than after analysing the shadow prices we ran 3 variants, where we modified the profit contribution of turnsole (*LP_TURN*), the locust (*LP_LOCUST*) and the poplar (*LP_POPLAR*).

The production structure that we got after having solved the basic model can be seen in Table 6.

Table 6. Production structure for 6 years

Name	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Corn	2,50	2,50	2,50	2,02	2,50	2,50
Turnsole				0,62		
Winter wheat	0,92	0,96	0,96	0,78	0,96	0,96
Winter colza	1,00	0,96	0,96	1,00	0,96	0,96
Locust						
Poplar						
Willow	0,58	0,58	0,58	0,58	0,58	0,58

Source: own creation

As we can see in this table, in the production structure corn has an absolutely superiority compared to the other crops for the *period of 6 years*. Corn used up at 100 percent its available maximum field of 250 hectares. The exception was the 4th year, when its area reduced by 48 hectares, and turnsole got into its place by the area of 62 hectares. The winter wheat and the winter colza are on the 2nd and 3rd place with the area of 92-96 hectares. The smallest area has the Swedish willow with the area of 58 hectares.

The maximum *profit contribution* that can be reached by running this model *for 500 hectares and 6 years is approximately 388 million Ft.*

Analysing the basic model's production structure (Table 6.) we can see that the turnsole, the locust and the poplar did not get into. We must analyse the values of profit contribution if we want these crops to be competitive compared to the other field crops. The sensitivity analysis' table for variable cells provides us assistance for this. From this table we can read the shadow prices, marginal costs of the activities. It gives the information about why an activity did not get into the production structure and when it can get into the optimal solution. Besides, it shows with how much the coefficient of an activity must be increased in order to get into the production structure without the decrease of the objective function's value.

We summarized the table of variable cells of the first year's sensitivity analysis in Table 7.

Table 7. The summarized table of variable cells for the first year's sensitivity analysis of the linear programming model (100ha)

Name	Area under cultivation 100ha	Shadow price of the activity eFt/100ha	Objective function value eFt/100ha	Lower limit	Upper limit
Corn Year 1	2,50		14781,1	12556,5	14781,1
Turnsole Year 1		**-3501,94**	**8790,6**	**….**	**12292,6**
Winter wheat Year 1	0,92		12802,6	9300,6	13413,7
Winter colza Year 1	1,00		12514,7	11903,6	12514,7
Locust Year 1			**-50533,5**	**….**	**-18016,6**
Poplar Year 1			**-42367,4**	**….**	**21074,4**
Willow Year 1	0,58		-53117,0	-85633,9	-32361,1

Source: own creation

From this table it can be seen that turnsole (with 87.906 Ft/ha profit contribution) did not get into the production structure. In case if the value of profit contribution would be increased to 122.926 (Figure 1.), than beside the maximum use of the existing resources it would get into the production structure at the expense of wheat and rape (Table 8.).

For the affection of changes, among the woody orchards the willow's role in the production structure would change, since it would occupy the one-third of the total area. However, the locust and the poplar still did not get into the production structure. In accordance with the basic production structure the area of rape has decreased, since it would get into the management only in the fourth year.

Table 8. Production structure for 6 years if the objective function coefficient of turnsole is increased to the minimum threshold price (100ha)

Plant/Year	1st	2nd	3rd	4th	5th	6th
Corn	2,50	2,50	2,50	1,40	2,50	2,50
Turnsole	1,00	1,00	1,00	0,82	1,00	1,00
Winter wheat	0,50	0,50	0,50	0,78	0,50	0,50
Winter colza				1,00		
Locust						
Poplar						
Willow	1,00	1,00	1,00	1,00	1,00	1,00

Source: own creation

5.1.1. The change of the locust's PC value compared to the basic model

From Table 7. we can see that the locust did not get into the basic model's production structure, either. In case if we would like to get a *woody enery orchard* into the production structure instead of the turnsole, than the locust's profit contribution for the first year should be increased from -505.335 Ft to -180.166 Ft. This value was determined by the value of allowable increase in the basic model, which was 32.516 Ft per one hectare. The coefficient of the objective function and the allowable increase must be summed in order to get this value, so in this way we got 180.166 thousand Ft per 100 hectares. The lower profit contribution value was determined like this, and locust would be competitive with the other arable crops under these conditions.

In the present economic state there is not any opportunity for the growth of the locust's profit contribution, however, since the cost of locust cutting for one hectare is approximately 288 thousand forint. Further cost are the handling, cultivation, material and other cost elements. But in case of this reduce would happen in a certain way, than compared to the basic model the locust and the willow would get into the production structure with 34 and 24 hectares (Table 9.).

Table 9. Production structure for 6 years if the objective function coefficient of locust is increased to the minimum threshold price (100ha)

Plant/Year	1st	2nd	3rd	4th	5th	6th
Corn	2,50	2,50	2,50	2,02	2,50	2,50
Turnsole				0,62		
Winter wheat	0,92	0,96	0,96	0,78	0,96	0,96
Winter colza	1,00	0,96	0,96	1,00	0,96	0,96
Locust	0,34	0,34	0,34	0,34	0,34	0,34
Poplar						
Willow	0,24	0,24	0,24	0,24	0,24	0,24

Source: own creation

5.1.2. The change of the poplar's PC value compared to the basic model

The poplar did not get into the basic model's production structure either (Table 7.). Its profit contribution value should be featured in the model by positive value (210.744 Ft/hectares). This major change is needed, because in the harvesting year this enterprise bears the lowest specific profit contribution.

Table 10. Production structure for 6 years if the objective function coefficient of poplar is increased to the minimum threshold price (100ha)

Plant/Year	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
Corn	2,50	2,50	2,50	2,02	2,50	2,50
Turnsole				0,62		
Winter wheat	0,92	0,96	0,96	0,78	0,96	0,96
Winter colza	1,00	0,96	0,96	1,00	0,96	0,96
Locust						
Poplar	0,34	0,34	0,34	0,34	0,34	0,34
Willow	0,24	0,24	0,24	0,24	0,24	0,24

Source: own creation

If the poplar's profit contribution would reach the minimum marginal cost value, than Swedish willow could also be in the planned production structure (Table 10.). The area sown of the other crops are the same with the values in the basic model.

5.2. Analysis of the simulation model

In the course of our work after structuring and running the multiperiodic linear programming model we made a simulation model consisting the same conditions as we set at the linear programming model. The results of the linear programming model and the Monte Carlo-simulation were compared. We managed the profit contribution of the enterprises as variables with normal distribution. We applied the *Crystal Ball* programme package by which we could find the extreme of the objective function and specify the constraints for the resources within the optimal crop structure.

In the simulation model we set the influence variable, their *probability distributions, the relation between variables*, and the *intervals of the elements' possible change*. We originated the interval and distribution values by random number generation.

In the course of the analysis we calculated with the same economic conditions as at the linear programming model. For the constraints we applied the available resources and observed the rules of rotation cycle. These specific data were *deterministic within the model.*

The profit contribution values of the enterprises are considered as *variates* which was determined by normal distribution in the first year, than from the next year the rate of the annual income and cost increases were considered.

The decision variants were the areas of the enterprises. In the course of making the simulation we choose values according to probability distribution assigned to each uncertainty factor. By using these parameters we made 10.000

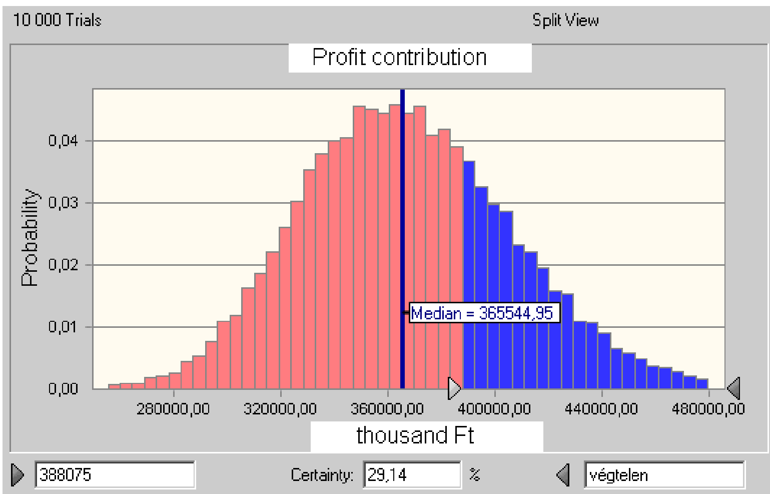
simulationsfor the sake of reaching the maximum profit contribution under the maximum use of the given resources.

Then we analysed the evolution of the objective function by statistical methods, and we created decision variants in accordance with the decision-maker's exposure.

We summarized the results of the linear programming model and the simulation in Table 11. Since we ran the model 10.000 times, we will not report each result in this paper. In the first three coloumns of the summary table the production structure with the highest (PC_max) and the lowest (PS_min) maximum profit contribution is given.

According to the given parameters, the value of the average profit contribution *with simulation* is 427.302 thousand Ft for 6 years and 500 hectares (Table 11., Table 12.), which probability of occurring is 59.9 percent. The value of the average profit contribution with the optimization of linear programming model is 388.075 thousand Ft for 6 years and 500 hectares, which probability of occurring is 80 percent. If we consider the production structure of the linear programming model as permanent when doing the simulation, than the probability of reaching the maximum PC value of the LP is 29.14 percent (Figure 1.).

Figure 1. The profit contribution values by the simulation running



Source: own creation

The median of the simulation model's profit contributions is 365 million Ft, i.e. we experienced at 50 percent of the runs less income than this value (in 6 years on 500 hectares).

The *maximum income* is 466.279 thousand Ft for 6 years and 500 hectares, however, the choice of production structure with higher income entails high risk. This is backed by the high value of relative variance that we got in the course of the simulation model's running.

Table 11. The summerized results of the linear programming model and the simulation

Name		PC_max	PC_mean	PC_min	LP
PC (thousand Ft/6years/500ha)		**466279**	**427302**	**123219**	**388075**
Year 1					
Corn	Area under cultivation (hectare)	250	97,5	121,8	250
Turnsole		-	100	-	-
Winter wheat		201,7	200,4	-	92,2
Winter colza		48,2	100	-	100
Locust		-	-	158,2	-
Poplar		-	-	120	-
Willow		-	2	100	57,8
Year 2					
Corn	Area under cultivation (hectare)	250	218	21,6	250
Turnsole		48,3	81,6	100	-
Winter wheat		201,7	198,4	0,2	96,5
Winter colza		100	100	-	95,7
Locust		-	-	158,2	-
Poplar		-	-	120	-
Willow		-	2	100	57,8
Year 3					
Corn	Area under cultivation (hectare)	250	128,9	21,6	250
Turnsole		100	100	-	-
Winter wheat		50	201,7	100,2	96,5
Winter colza		100	67,4	-	95,7
Locust		-	-	158,2	-
Poplar		-	-	120	-
Willow		-	2	100	57,8

Source: own creation

Table 12. The summerized results of the linear programming model and the simulation

Name		PC_max	PC_mean	PC_min	LP
PC (thousand Ft/6years/500ha)		**466279**	**427302**	**123219**	**388075**
Year 4					
Corn	Area under cultivation (hectare)	247,1	169,6	21,8	202,2
Turnsole		-	65,2	100	61,7
Winter wheat		152,8	163,1	-	78,3
Winter colza		100	100	-	100
Locust		-	-	158,2	-
Poplar		-	-	120	-
Willow		-	2	100	57,8
Year 5					
Corn	Area under cultivation (hectare)	249,8	110,6	21,6	250
Turnsole		-	85,6	-	-
Winter wheat		150,1	201,7	0,2	96,5
Winter colza		100	100	100	95,7
Locust		-	-	158,2	-
Poplar		-	-	120	-
Willow		-	2	100	57,8
Year 6					
Corn	Area under cultivation (hectare)	242,8	199,3	121,8	250
Turnsole		-	37,8	-	-
Winter wheat		201,7	201,7	-	96,5
Winter colza		55,5	59,2	-	95,7
Locust		-	-	158,2	-
Poplar		-	-	120	-
Willow		-	2	100	57,8

Source: own creation

6. Evaluation of results

The aim of our research is to provide assistance for the persons in agriculture in supporting their decisions by methods that are suitable for the description of system relations that requires the simultaneous system-orientated consideration of many variables.

In the course of our work we made a multiperiodic linear programming model and a simulation model for modelling the crop structure, in which we competed arable crops and woody energy orchards as well. After having run the linear programming model we analysed the shadow prices of constraints and the marginal cost of the variables. Considering the results of the analysis and professional information we made a sensitivity analysis, which gave a basis to create new decision variants.

In our research we analysed that by how much profit contribution can be considered the energy orchards as competetive beside arable crops.

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