SZENT ISTVÁN UNIVERSITY
GÖDÖLLŐ
Management and Business Administration PhD School

THESES OF PhD DISSERTATION

OPTIMIZATION OF BIOMASS PRODUCTION ON COMPANY LEVEL

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1. INTRODUCTION

1.1. Premises of the research

In the past few years I - as a member of the research group - participated BIOENKRF research program No. 5.2 called “The complex economic analysis of operating bioreactor, determining the system conditions (border points), its’ coherencies with in- and output characteristics and reversibility”. During the development of the Hungarian Biomass Model I contributed in the constitution of the model and drawing the possible target functions. I am dealing with linear programming long since. During my teaching activities formerly I was the leader of practical lessons in Operational research, currently I give lessons in this subject within the framework of ERASMUS training.

1.2. The aim and scope of the research

In agriculture mathematical models are used for a long while to unburden decisions and to make optimization calculations. (Csaba Csáki, László Csete, Imre Ertsey, Sándor Mészáros, László Szelényi, Károly Szenteleki, István Szűcs, József Tóth, or from abroad I mention Ackoff, Beer, Chow, Gisser, Heady, Kravcsenko, Platonov, Popov, Sasieni, Windsor professors - without attempting to be comprehensive.) Using mathematical methods supporting decisions was prevailing from the 1960’s to 1980’s. In Hungary, interest for using system-optimizing models decreased in the last two decades. This is partly because the results could be hardly used in practice or the expected results did not come. On the other hand in the 1990’s the big problem of transformation of the company structure and property relations engaged the attention of agricultural economists as a consequence less energy was left to apply economic calculations in order to help more effective production. At the same time in Western-European countries – as part of the consultation system – “optimization” services which help companies to develop production structures are still taken seriously. Before the transition period between political regimes, agricultural plants, state farms and farmers’ co-operative with several thousand hectares of land generally produced several plant and animal breeds, and had the opportunity to apply several technologies. Beyond their basic activity they had sub-plants, industrial, commercial or service branches. Creating the complex plans was a complicated computer engineering job. These complex development company plans constructed for one or more years were made with external experts. Nowadays most agricultural companies farm on 50-500 hectares. Less plant breeds are grown, and often no animals are kept. Farms have less machines. The product structure is simpler, and so the production plan. In these small size farms they do traditional planning. However only those producers can keep pace in economic competition who can adapt to new challenges, environmental and conservation aspects. It can only be executed with optimization planning considering possibilities.

The **aim** of my research is to work out such a planning-decision preparation model for agricultural entrepreneurs thinking in biomass production which can be used simply and without serious mathematical qualification. After the adaptation of the basic model plans, plan-variations can be done fast and easy, thus reasonable decisions can be made.

During my research I had three aims. **First** to compile a model for farmers which assists in decision making concerning production structure – particularly to determine the optimal rate among food products and give such a methodological solution – using the up-to-date informatics possibilities – which gives a background that can be adjusted to any kind of farm sizes.

My **second** research aim is to compose an easily reviewable, flexible LP model. The model is a case study made for a certain sample farm, sample technology that is Tass-puszta but it can be adapted to any other farms as well. Possible plants, resource-limits and market potentials can vary from farm to farm. The situation is the same concerning yield. Prices always vary and this change can be handled according to the logic of the system.

My **third** aim is to prepare the 'copyright' version of the model on a CD format. The basic model can be found on this CD which contains a database containing plants considerable concerning energy biomass production with technology parameters, proposed condition system and target functions – which can be adjusted to parameters of the given farm. Filled with the given farm's data the plan-versions can be prepared fast and easy. The system can be operated with a version simplified by myself of WINQSB software used also at Operation research subject.

According to the above my thesis has three major units.

In the first part I submit bibliography adaptation results. This chapter begins with introduction of mathematical models then I pan out about methods suitable for analyzing production efficiency.

The next part of bibliography adaptation I describe concepts related to energetic utilization of biomass and give a short view about the production and utilization practice of bio-fuels in major bio-energy user countries, in EU-states and Hungary.

In the **second** unit of the thesis I demonstrate those databases and methods which served to reach my research aims.

The **third** part begins with the description of the model worked out in the framework of BIOENKRF research project and ends with its solution, sensibility studies, calculation of efficiency and demand indices and review of conclusions.

1.3. Actuality of the topic

Nowadays exploitation of traditional resources – crude oil, natural gas and coal – are more and more expensive. Harmful environmental effects during their use are becoming more threatening. The growth of mankind goes along with increasing energy consumption which can be covered by fossil fuels only for few decades. Energy needed for economic-social improvement is therefore gradually and significantly appreciated.

Renewable energy resources could mean a long-term solution in order to satisfy the energy need of humanity. Among renewable energy resources the energetic use of biomass should be emphasized as it makes possible the economical and versatile use of the Sun's energy. Bio-fuels produced from biomass are presently more expensive in most countries than fossil fuels however their use due to political measures flares worldwide.

Discrepancy can be observed worldwide between the satisfaction of food necessity of the growing population and energetic use of agricultural land. Among some experts there are certain theories which see the world's food supply to be threatened. Among plants grown for food- and animal feed industry wheat, corn, sunflower, rape, potato and sugar beet can be used as energy-plants and therefore from this point of view it is a very important question how energetic and food production aims compete with each other.

2. MATERIAL AND METHOD

2.1. Databases used for the studies

During the collection of data I followed two principles. First, with collection and systematization of data of a chosen sample farm I built such a database which is suitable for examination and optimization of the farm's structure according to determined target functions or rather establishing a theoretical database with which it is possible to analyze the production structure of any kind of agricultural company.

For the preparation of the input table we need to take the resources and capacities into account, the technical-technological data of producible plants and then to determine the mathematical condition-system and target functions.

The concrete data collected are the following:

- Available land area,
- Labour force per month,
- Prime mover per month per machine-type,
- Available nutrient supply,
- Cost of plant protection,
- Specific yields,
- Production costs and profits,
- Profitability indices representing resource exploitation,

- Possible raw materials and gas-yield of biogas production,
- Possible raw materials of bio-ethanol production and the quantity of extracted ethanol,
- Average yield of plants suitable for bio-diesel production.

For description of the condition system and the target functions the data were collected in the Tass-puszta sample farm however I also used data from bibliography and internet pages and information received from company experts working in production - Középtiszai Rt. Kunhegyes, Bátortrade Kft. Nyírbátor.

The Tass-puszta sample farm provided me data from the last 5 years about plants produced on 480 hectares of land, the quantity of used physical work, machine work per month, type and procedure and the quantity of used fertilizers and plant protection costs per plant-types. In case of potentially producible plants present in the model I worked with data from the Research Institute of Agricultural Economics and the Agricultural Machinery Institute, and also used the data from literature - **Antal** (2005), **Bai** (2007), **Gyulai** (2006), **Radics** (2008). The averaged data per hectare were built into the model.

2.2. The applied data-analyzing methods

The methodological pith of my research was the suitable and adjustable adaptation of linear programming problem perfectly appropriate for analyzing production structure. The general description of the used model can be found inter alia in books of **Krekó** (1966), **Felleg-Ugrósdy** (1998) and **Tóth Z.** (2009).

In the **linear programming model** the condition-system and the target-function contain only primal relations.

$$\begin{array}{rc} \mathbf{x} \geq \mathbf{0} & \textit{non-negativity condition} \\ \mathbf{Ax} \leq \mathbf{b} & \textit{linear condition-system} \\ \hline \mathbf{c} * \mathbf{x} \rightarrow \textit{extr.} & \textit{target function} \end{array}$$

I execute the optimization of the biomass model by the help of **WINQSB** computer program which is made for Windows operation system and can be freely downloaded from the Internet. After development of the linear programming problem the model can be run and as a **primal solution** of the linear programming problem the optimal production structure can be determined. Other tables of the computer program show how much is used from each resources, in case of which resources have free capacities. The dual solution can be read out, the shadow prices, reduced costs can be determined.

Shadow prices and reduced costs can be used for the **sensibility test** of linear programming problem. Knowing the **shadow prices** the exhausted resources can be evaluated, namely we can study how much we can change the components of the **b** capacity-vector in order the optimal solution not to change. In case of a variable not used in production **reduced cost** means how much the value of this variable's co-efficient in the target function has to be corrected in order to get into the program.

3. RESULTS

According to research aims I made an LP model for optimizing biomass production on company level, which helps agricultural entrepreneurs plan their economic structure and utilize resources.

During studying the bibliography I found out that many models are known which describe the economic effect of bio-energy plants and the area change that can be agriculturally utilized. In case of known land utilization models I strained after domestic adaptations but it was inefficient. As input data they demanded too much information which were not registered among the registration data of farmers, there is no regional service which can help the farmers to access the necessary data or the achievability of the needed data would cost a lot of money and time. Most of the studied models are too complicated that they could be suggestible to Hungarian farmers as user-friendly applications and which could be applied simply and without special preparation and costs. Because of these causes a new model became necessary which I named the **Biomass Production Model.**

Model-calculations underlying company plans have three major stages.

a) Definition of the input system, composition of the input table system underlying the fill-up of the model. This work-process with involvement of company experts aims at the estimation of the important parameters of activities present in the calculation and consideration of professional coherencies which will probably have impact on next years' proposed numbers.

b) Execution of actual model-calculations. After fill-up of the developed linear programming problem and determination of target-coefficients the solution can be calculated by the help of the computer, the optimal production structure can be determined.

c) Evaluation of calculation results, balancing of different alternatives, professional controlling and judgement of information referring to the direction of improvement, series of common consultations of experts making planning and doing business. In case of development demands of new alternatives, new thoughts born during the evaluation the input-pages may be modified and calculation can be repeated. In the course of this we can define the "competitiveness" of energetic purpose production which is predicted by experts to have great perspectives.

3.1. The Tass-puszta model of biomass production

Optimization model of biomass production is based on linear programming and it allows me to determine the optimal crop structure for a chosen agricultural area, in case of different target-functions. The major question of the decision is whether it worth producing for food-industry or energetic purposes beside the available land area and resource capacity. For the sake of generalization I intended to solve a model which can represent optimization for biogas, bio-ethanol and bio-diesel end-products. I prepared the model for such companies which earnestly want to produce or directly use bio-energy. The structural logic of the model is shown on *Figure 1*.

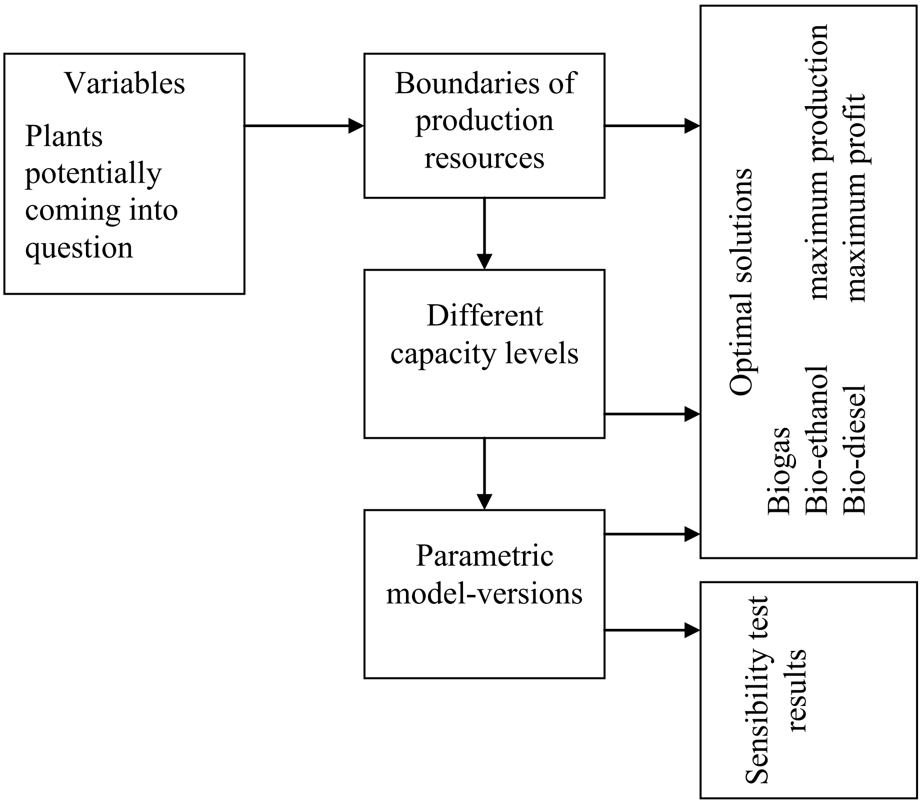

Figure 1: The structural logic of the model

Source: Szűcs I. et al. (2009)

Nowadays it is a realistic prospect to found an "energy farm". Considering that two third of operational costs of such investments are raw material costs it is a relevant question how energetic and food production purposes compete with each other. Estimating the model parameters I considered investment-economical cost-yield relations of a model-level energy producing company. In this I relied on calculations by **Szűcs I**. et al. (2008).

As energy-plant mainly different fast-growing, more often producible and great mass giving tree species can be taken into account although some plants used in arable farming and produced for food industry (such as wheat, corn, sunflower, rape, potato, sugar beet) can also be used as energy-plants.

Selection of plants coming into question concerning production was based on the simple production structure of Tass-puszta sample farm however also keeping the possibility of generalization open. I completed the production structure with some so-called possibly producible plants and I also determined production parameters for them which were built into the model.

Variables of the model are summarized in *Table 1*.

Table 1: ***Variables of the Tass-puszta model***

Denomination	Variable	Unit	Denomination	Variable	Unit
Wheat	x_1	ha	Potato (energetic)	x_{10}	ha
Wheat (energetic)	x_2	ha	Sugar beet	x_{11}	ha
Oat	x_3	ha	Sugar beet (energetic)	x_{12}	ha
Oat (energetic)	x_4	ha	Sunflower	x_{13}	ha
Rye	x_5	ha	Sunflower (energetic)	x_{14}	ha
Rye (energetic)	x_6	ha	Rape	x_{15}	ha
Corn	x_7	ha	Soy	x_{16}	ha
Corn (energetic)	x_8	ha	Sugar sorghum	x_{17}	ha
Potato	x_9	ha	Sweet potato (girasole)	x_{18}	ha

Source: own compilation

Condition system of the model

In order to prepare the input table of the model we need to take the resources and capacities and the technical-technological data of producible plants into account and then determine the mathematical condition-system. Before determining the condition-system I must mention that production technologies with different production aims are the same because for example there is no significant difference between technology of feeding and that of bio-fuel corn production thus competitiveness depends on the difference between the marketing channels of the end-product.

Framing of balance conditions:

- Determining the non-negativity conditions.
- Composing the balance conditions of land area usage. Variables mean the sowing area of the certain plants. (The land area is mostly qualitatively divided, the area of a company is generally composed by many types of soil thus it can be necessary to build the divided balance conditions into the model according to different soil-types. The simplified model is not specified for this.)
- According to viewpoints of crop rotation we must determine the maximum sowing area of the certain plants with introduction of unique barriers.

We only note down the labour force and machine capacity for the rush-season because in all other seasons they are not determinative considering production structure. In this way we can significantly decrease the number of balance conditions or rather the size of the model without influencing the solution. Simplification deviating from reality came because of better transparency.

According to technology the following rows can be inserted into the model:

- Labour force need (hour/ha) in the 8^{th}, 9^{th} and 10^{th} months.
- Prime mover need (hour/ha) in the 1^{st}, 2^{nd} and 3^{rd} seasons.
- 2^{nd}-type machine need (hour/ha) in the 1^{st}, 2^{nd} and 3^{rd} seasons.
- 3^{rd}-type machine need (hour/ha) in the 1^{st}, 2^{nd} and 3^{rd} seasons.
- The necessary fertilizer quantity (kg/ha) nitrogen, phosphorus and potassium agents.

I prepared the input table according to the balance conditions *(Table 2)*.

Target-functions of the model

- Achievable maximum profit.
- Maximum quantity of producible biomass.
- Maximum quantity of biogas producible from the producible biomass.
- Achievable maximum profit in case of biogas production.
- Maximum quantity of bio-ethanol producible from the producible biomass.
- Achievable maximum profit in case of bio-ethanol production.
- Maximum quantity of bio-diesel producible from the producible biomass.
- Achievable maximum profit in case of bio-diesel production.

The target functions are summarized in *Table 3*.

At the maximum quantity of biogas producible from the producible biomass I used indices calculated by myself from net energy content. In case of achievable maximum profit of biogas production I calculated with an average profit of 10 Ft/m^3.
In case of bio-diesel we can not optimize for maximum profit because the production cost and takeover price are equal: 262,5 Ft/l. The circle of considerable plants is narrow because of costs of oil extrusion.
At the calculation of the achievable maximum profit in case of bio-ethanol production I calculated with 160 Ft takeover price.

Table 2:
Input table

	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}	x_{16}	x_{17}	x_{18}		$\underline{b}$
	wheatf	wheaten	oatf	oaten	ryef	ryeen	cornf	cornen	potf	poten	sbeetf	sbeeten	rape	sflowf	sflen	soy	ssorghum	spot	relation	capacity
Area (ha)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	≤	480
Cornsmax66%	1	1	1	1	1	1													≤	320
Sbeetmax25%											1	1							≤	120
Rapemax25%													1						≤	120
Sunflmax25%														1	1				≤	120
labour07 (h/ha)	7	7	8	8	8	8	2	2	1	1	1	1	1	1	1	1	1	1	≤	520
labour09 (h/ha)	1	1	1	1	0,5	0,5	2	2	4	4	2	2	0	2	2	0	0	0	≤	800
labour10 (h/ha)	2	2	2	2	1	1	7	7	4	4	0	0	0	1	1	0	0	0	≤	520
prmover-1 (h/ha)	1	1	1	1	2	2	0	0	1	1	0	0	1	1	1	0	0	1	≤	820
prmover-2 (h/ha)	1	1	0,9	0,9	1	1	0,1	0,1	1	1	2	2	0	2	2	0	1	0	≤	820
prmover-3 (h/ha)	4	4	0,8	0,8	1	1	2	2	1	1	0	0	1	1	1	1	1	0	≤	820
2-mach-1 (h/ha)	1	1	1	1	2	2	0	0	1	1	0	0	1	1	1	0	0	1	≤	900
2-mach-2 (h/ha)	1	1	0,9	0,9	1	1	0,1	0,1	1	1	2	2	0	2	2	0	1	0	≤	900
2-mach-3 (h/ha)	4	4	0,8	0,8	1	1	2	2	1	1	0	0	0	1	1	1	0	1	≤	900
3-mach-1 (h/ha)	1,5	1,5	1,5	1,5	3	3	0	0	0	0	0	0	1	0	0	0	0	0	≤	400
3-mach-2 (h/ha)	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1	1	0	≤	400
3-mach-3 (h/ha)	0	0	0	0	0	0	2	2	4	4	0	0	0	1	1	0	0	1	≤	400
N agent (kg/ha)	121	121	70	70	53	53	168	168	125	125	230	230	126	100	100	124	140	200	≤	70000
P agent (kg/ha)	50	50	30	30	25	25	66	66	50	50	115	115	80	75	75	74	70	75	≤	500000
K agent (kg/ha)	81	81	73	73	55	55	180	180	225	225	360	360	100	175	175	102	70	250	≤	300000

Source: Own compilation on the basis of data of the sample farm and literature sources

Table 3:

Summarizing table of target-functions

	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}	x_{16}	x_{17}	x_{18}		
	wheatf	wheaten	oatf	oaten	ryef	ryeen	cornf	cornen	potf	poten	sbeetf	sbeeten	rape	sflowf	sflen	soy	ssorghum	spot		target
Ach.max.profit	100	110	80	86	80	86	105	125	300	360	160	200	130	125	137	120	190	180	=	max
Biomass max	5	7,5	3	4,5	2,5	4	6	11	25	40	40	50	2,5	3	6	2	35	50	=	max
Max bio-gas	2565	3040	1710	2052	567	852	3828	5423	2198	307	4104	4788	1626	2280	2850	1680	2256	1400	=	max
Bio-gas max pr	25,65	30,40	17,10	20,52	5,67	8,52	38,28	54,23	21,98	3,07	41,04	47,88	16,26	22,80	28,50	16,80	22,56	14,00	=	max
Bio-ethanol	1500	1725	900	1035	750	885	2300	2675	2000	2750	4000	4500					4700	5000	=	max
Bio-eth max pr	75,00	69,00	45,00	41,40	37,50	35,40	161,0	160,5	280,0	522,5	200,0	180					470,0	450,0	=	max
max bio-diesel				217			172						600	980		400			=	max
diesel max pr				56,96			45,15						157,5	257,3		105,0			=	max

Source: Own compilation on the basis of data of the sample farm and literature sources

3.2. Evaluation of model-calculation solutions

After computer input of the formerly circumscribed basic data, upload of input table-system of the linear programming problem and determination of the target co-efficients the solution of the problem can be calculated by the help of the computer and the optimal production structure can be determined.

Calculation solutions of the basic model

In case the target is the achievable maximum profit, the optimal production structure:

Potato (energetic purpose)	100 ha
Sugar beet (energetic purpose)	120 ha
Rape	120 ha
Soy	140 ha
Achievable maximum profit:	92 400 000 Ft

In case the target is the maximum quantity of producible biomass, the optimal production structure:

Sugar beet (energetic purpose)	120 ha
Sweet potato	360 ha
Achievable maximum biomass quantity:	24 000 tons

For the crop land of sweet potato it would worth to put a limit – eg. not to reach 10% of the whole area. In case of this the optimal crop structure is the following:

Corn (energetic purpose)	32 ha
Potato (energetic purpose)	72 ha
Sugar beet (energetic purpose)	120 ha
Sugar sorghum	208 ha
Sweet potato	48 ha
Achievable maximum biomass quantity	18 912 tons

In case of maximizing for bio-gas quantity wheat should be produced on 3.75, corn on 22.5, potato on 88.75, sugar beet on 120, rape on 120, sugar sorghum on 120 hectares, in order to reach the maximum quantity of producible bio-gas. In this case the achievable maximum bio-gas quantity is 1 446 901 m^3. Calculating with 10 Ft/m^3 profit the achievable maximum profit can be 14 469 010 Ft.

The maximum producible quantity of bio-ethanol from producible biomass

In case the crop land of sweet potato and sugar sorghum is not limited the optimal production structure contains only these two plants. The achievable maximum quantity of bio-ethanol in this case may reach 2 292 000 liters.

In case we limit the crop land of sweet potato and sugar sorghum to 10-10% other plants also get place in the optimal production structure, however the achievable maximum quantity of bio-ethanol can only be 1 322 459 liters.

Achievable maximum profit in case of bio-ethanol production

In case the crop land of sweet potato and sugar sorghum is not limited the theoretically achievable maximum profit may be 224 000 000 Ft.

The achievable maximum quantity of bio-diesel is 285 600 liters in case the crop land can be used for producing rape, sunflower and soy where the achievable maximum profit may be 74 970 000 Ft.

Summarizing the results, projected to the same area, after solving the optimization problem the following profit mass can be prognosticated:

– In case of optimization for food production:	92 400 000 Ft
– In case of maximization for bio-gas	14 469 010 Ft
– In case of optimization for bio-diesel	74 970 000 Ft
– In case of optimization for bio-ethanol	224 000 000 Ft

The studied farm already has a bio-gas plant. Analyzing the size of the achievable profit mass on 480 hectares of area it can be stated that biogas production reaches only a small fraction (15.66 %) of food or feeding production. This means that only byproducts worth using for biogas production, the main products must be sold.

In case of Tass-puszta sample farm considering the ecologic features a bio-diesel plant can be established, a so-called energy farm can be developed. In case they would produce plants suitable for bio-diesel production – namely sunflower, rape and soy – on their entire crop land and the total yield would be transformed to bio-diesel, profit mass coming from the 480 hectares would be only 81.14% of the profit coming from food and feeding production so that the investment of the bio-diesel plant would not be considered.

The possibility of establishing a bio-ethanol plant also came up at the sample farm. Based on my calculations plant production for bio-ethanol production and energetic-purpose own processing can be considered more economical than food- or feed-purpose production. From the plants produced on the area suitable for bio-ethanol production the theoretically maximum quantity of retrievable bio-ethanol is 2 292 000 liters. However, because of agro-technical considerations, with putting area limit for sugar sorghum and sweet potato we can calculate far more modest but much more realistic – 1 322 459 liters – quantity for bio-ethanol, which is 16.5% more than profit expected in case of food- or feed-purpose production.

Those agricultural companies which produce biomass for energetic purposes may receive higher Single Area Payment Scheme (SAPS). This can increase the profit per hectare with 10-15% contrary to food purpose disposal. Higher SAPS can only be received in case the company makes a long-term contract with a given bio-energy producing plant. According to experiences, farmers dislike undertaking these contracts because of weather conditions – more drought years after each other, early freezes, desolating sowings because of floods – harvest fluctuations are high.

Thus the received solution must be analyzed in details. Knowing the shadow prices – dual variables – or the evaluation price of used up resources the program can be modified. The upcoming problems can be solved by increasing the size of the model, giving more details, describing relations, increasing capacity, inducing new activities, introducing new limits. New thoughts, new alternatives emerging during evaluation input pages may be modified and calculations may be repeated. This way we can interpret the "competitiveness" of energetic purpose production.

3.3. Sensibility and efficiency tests

In case of some plants I executed sensibility tests concerning the effect of factor usage change. Accordingly I studied how the change of input-output prices affect production structure, how the competitive position of some bio-energetic end-products depend on resource capacity change, how the optimal crop structure and achievable maximum profit is influenced in case the quantity of area, labour force, chemical fertilizer and machine capacity increases or decreases by 10-20-30%. Along of change how the below efficiency and demand indices shape in case of biogas, bio-ethanol and bio-diesel production:

efficiency indices:

- product per hectare
- profit per working day
- profit per machine-day

and **demand indices**:

- area needed to produce one ton of product
- manpower needed to produce thousand Forint
- machine work used to produce thousand Forint

In the course of **sensibility test** we can study the maximum price-change by which the present production program stays optimal – namely how much we can change the co-efficients of the target function in order the optimal solution remain unchanged and how the profit alters in case of price change. From another viewpoint we can analyze the change of capacity vectors because beyond a certain limit – in case we use more from a given resource – paucity of the other resources will affect revenue increase.

In case the aim is to achieve maximum profit (1st target function) **the primal solution** (the optimal production structure) is: potato (energetic) 100 ha; sugar beet (energetic) 120 ha; rape 120 ha; soy 140 ha – the achievable maximum profit is 92 400 000 Ft.

From the table given by the program the **reduced costs** of each plants can be read out. Wheat, oat, rye, corn, food potato, food sugar beet and sugar sorghum do not occur in the basis solution. These so-called free variables have reduced costs. The admissible minimum and maximum give the limit of the suitable target function coefficient change within which the optimal solution of the problem does not change (of course the value of the target function does).

For example the reduced cost in case of food wheat is -20. This means that wheat can get into the optimal solution if we can reach 20 000 Ft more profit, namely 120 000 Ft profit per hectare. In *Table 4* I made calculations with increasing the target function co-efficient of wheat by 10-20-30%. If profit per hectare is less than this the program does not chose wheat into the basis. Calculating with target coefficient between 0 and 119 000 Ft the optimal production structure and of course the value of the target function remains the same. Above 120 000 Ft however the reduced cost changes. According to this we would receive the same optimal solution until 840 000 Ft profit only the value of the target function would change.

Table 4:

The place of wheat in the production structure in case of different profit-levels per hectare

Wheat profit Ft/hectare		- 30%	-20%	-10%	100%	+10%	+20%	+30%
		84	96	108	120	132	144	156
x_1	Wheat (food and feed)				6,7	6,7	6,7	6,7
x_{10}	Potato (energetic)	100	100	100	100	100	100	100
x_{12}	Sugar beet (energetic)	120	120	120	120	120	120	120
x_{13}	Rape	120	120	120	120	120	120	120
x_{16}	Soy	140	140	140	133,3	133,3	133,3	133,3
Maximum profit (thousand Ft)		92400	92400	92400	92400	92480	92560	92640

Source: own calculations

From **the dual solution table** we can read out how many was used from each resource, is there any free capacities. Those resources have "**shadow price**" which were totally used in the optimal production structure.

If the aim is to achieve maximum profit then we can find shadow price at the area, crop rotation and the 3rd period of the 3rd machine. The shadow price of the area is 120 000 Ft thus if we would increase the available area with 1 hectare, the profit would increase with 120 000 Ft. At crop rotation we can not change because of agro-technical and plant protection reasons.

If we increase the capacity of the 3rd machine (harvester) with one unit (one man-hour) the profit would be 60 000 Ft more. The optimal production structure does not change substantially until 520 man-hour capacity.
From the table of the computer program we can say that the production structure would not substantially change between 340 and 520 hectares of area, the same plants are chosen by the program by their profitability order. However, under 340 hectares or above 520 hectares other plants enter. Changing the size of area unique limits because of crop rotation may also vary, the extent of used resources alters also as well as their shadow price.

Change of area size

The shadow price of area was 120 000 Ft thus if we can hire more area the achievable profit would increase by 120 000 Ft per hectare. However crop rotation limits the maximum space of each plant. Knowing this I run the program after increasing and decreasing the size of area by 10-20-30% and studied how the crop structure and achievable profit changes. These results are summarized in *Table 5*.

Table 5:

The effect of area change on optimal crop structure and expectable profit considering crop rotation

Area (ha)	- 30%	-20%	-10%	100%	+10%	+20%	+30%
	366	414	432	480	528	576	624
Potato (energetic)	100	100	100	100	100	100	100
Sugar beet (energetic)	91,5	103,5	108	120	132	144	156
Rape	91,5	103,5	108	120	132	144	156
Soy	82	107	116	140	156	132	108
Achievable max.pr.(thou Ft)	76155	82945	86560	92400	98280	99360	100440

Source: own calculations

Table 6: ***The alteration of efficiency and demand indices according to used area change***

	-30%	-20%	-10%	100%	10%	20%	30%
Used area(ha)	366	414	432	480	528	576	624
Achievable max.pr (thou Ft)	76155	82945	86560	92400	98280	99360	100440
Thousand Ft/ha	208,07	200,35	200,37	192,50	186,14	172,50	160,96
ha/thousand Ft	0,00481	0,00499	0,00499	0,00519	0,00537	0,00580	0,00621

Source: own calculations

Calculations concerning effectiveness of used land is contained by *Table 6*. With increasing resource capacity profit per hectare reduces so efficiency of area deteriorates. Demand index, namely used area size per thousand Ft however increases.

Changing machine work capacity

Shadow price of the 3rd period of the 3rd machine was 60 000 Ft thus if we can hire such (harvester) machine profit would increase by 60 000 Ft per machine work hour. I run the program after increasing and decreasing the capacity of the 3rd period of the 3rd machine with 10-20-30% and studied how the optimal solution and value of target function changes. Results are summarized in *Table 7*.

Table 7: ***The effect of capacity change of the 3rd machine in the 3rd period on optimal crop structure and expectable profit***

Capacity of the 3rd machine in the 3rd period (machine work hour)	- 30%	-20%	-10%	100%	+10%	+20%	+30%
	280	320	360	400	440	480	520
Potato (energetic)	70	80	90	100	110	120	130
Sugar beet (energetic)	120	120	120	120	120	120	120
Rape	120	120	120	120	120	120	120
Soy	170	160	150	140	130	120	110
Achievable max.pr (thou Ft)	85200	87600	90000	92400	94800	97200	99600

Source: own calculations

In brief if we change the capacity of the 3rd machine in the 3rd period between 0 and 520 machine work hour the sown area of potato and soy is modified less but sown area of sugar beet and rape does not change.

If it is possible to hire more machine and increase machine work hours by 10-20-30% in the 3rd period (harvest) then optimal crop structure changes a bit but maximum profit increases by the product of the shadow price of machine work hour and number of machine work hours. In other words if the shadow price is 60 000 Ft and 10 % change means 40 machine work hours then the achievable profit per processed versions will be 2 400 000 Ft more until another resource will not be exhausted and enters as a limit.

We can illustrate the relation between the number of machine work hours and achievable maximum profit on a scatter plot (*Figure 2*). On the basis of definition of shadow prices it is obvious that within a given interval the relation can be depicted by a linear function, namely if use of machine work hour would increase with 1 unit in the 3rd period of the 3rd machine then the achievable maximum profit would increase with 60 000 Ft.

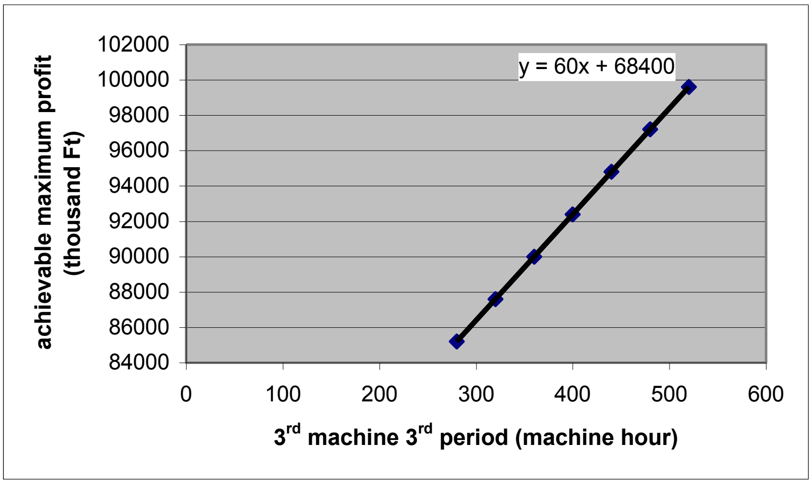

Figure 2: Relation between the capacity of the 3rd machine in the 3rd period and maximum profit

Source: own calculations

Table 8: ***Change of capacity of the 3rd machine in the 3rd period and change of efficiency and demand indices***

Capacity of the 3rd machine in the 3rd period (machine work hour)	-30%	-20%	-10%	100%	10%	20%	30%
	280	320	360	400	440	480	520
Achievable max.pr.(thou Ft)	85200	87600	90000	92400	94800	97200	99600
Thousand Ft/machine hour	304,29	273,75	250,00	231,00	215,45	202,50	191,54
Machine hour/Thousand Ft	0,0033	0,0037	0,0040	0,0043	0,0046	0,0049	0,0052

Source: own calculations

From data of *Table 8* we can see that profit per one machine hour decreases with capacity broadening thus we can state that efficiency of the 3rd machine decreases in can of capacity increasing. This is owing to the fact that the program chooses those plants first which use the fewest from the given resource, where the efficiency of the resource is the biggest (here the soy, rape, potato and sugar beet). The more we have from a given resource the program can involve those plants one after the other into the optimal crop structure whose machine need is bigger.

Studying the demand index we can determine that machine hour used for producing thousand Forint increases with capacity broadening.

Results of program running with other target functions were analyzed according to the same method. Calculations can be found in my dissertation. Hereunder I only emphasize some details from analysis of results obtained in case of application of different target functions.

Run of the program with the second target function concerned the maximum quantity of producible biomass. I received shadow prices for area and the 2nd period of the 3rd machine. According to this at first I changed and studied the size of area in the model, how the quantity of producible biomass alters. I illustrated the relation between the area and the mass of biomass on a scatter plot. On *Figure 3* it can be clearly seen that with increasing the size of area the quantity of producible biomass will grow to a certain point, afterward it stagnates. Because of relative shortage of another resource man-power will be the exhausting resource at 521 hectares.

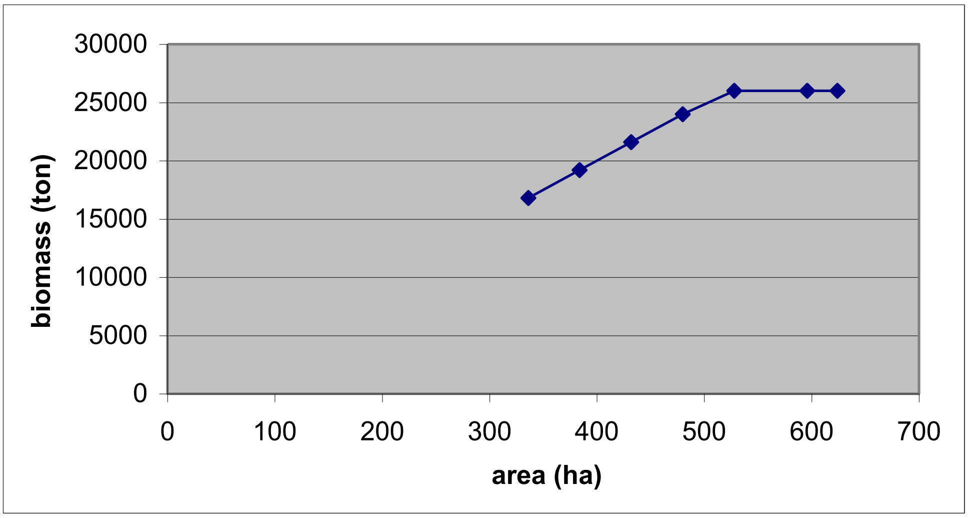

Figure 3: Relation between area size and quantity of producible biomass

Source: own compilation

Relation between the size of area and the quantity of producible biomass can be drawn with a piecewise linear function in a given range.

During analysis of efficiency and demand indices I found out that until size of 521 hectares the biomass quantity per hectare and the size of area needed for production of one ton of biomass do not change. Above 521 hectares enlargement of the area raises the biomass quantity in an increasingly smaller proportion. The cause of this in this case is that sugar beet is involved in the optimal crop structure as the plant giving the biggest biomass quantity but because sugar beet can only be sown into the same land four years after itself, it can only reach 25% in crop rotation.

In case we would set a 10% area limit for sweet potato the maximum producible biomass quantity would not increase above 521 hectares. Namely above 480 hectares more and more plants get into the optimal solution but their biomass quantity per hectare is smaller.

Similarly to area increase, because of crop rotation enlarging the capacity of the 3rd machine increases intensively the quantity of producible biomass only to a certain point. Concerning biomass quantity per one machine hour and machine work needed for producing one ton of biomass efficiency decreases above 360 hectares.

For maximum quantity of producible biogas from produced biomass – at running the program with the **3rd target function** – I received shadow price for human labour force in July and October. According to this I studied how the optimal crop structure changes in case I alter human labour force capacity simultaneously in July and October.

Table 9:

Effect of human labour force capacity enhancement on optimal crop structure

	- 30%	-20%	-10%	100%	+10	+20%	+30%
Labour force (man-hour)	364	416	468	520	572	624	676
Wheat (energetic)				3,75	9,2	14	19,6
Corn (energetic)		3,2	13,6	22,5	36,8	57,6	78,4
Potato (energetic)	61	68,4	80,8	88,7	74	48	22
Sugar beet (energetic)	120	120	120	120	120	120	120
Rape	63	101,2	120	120	120	120	120
Sunflower (energetic)	120	120	49,6				
Sugar sorghum			70,4	120	120	120	120
Biogas quantity(thou m^3)	1207	1309	1392	1447	1493	1544	1593

Source: own calculations

From data of *Table 9* we can determine that increasing labour force capacity significantly influences optimal crop structure.

Maximum quantity of producible bio-ethanol from producible biomass (*5th target function*) can be achieved if the optimal crop structure is: sugar sorghum 360 ha, sweet potato 120 ha. In this case the maximum quantity of extractable bio-ethanol is 2 292 000 liters.

The area has shadow price: 4700 liters. According to this I decreased and increased the size of area by 10-20-30 %. Modification of area size – if we do not limit the quantity of sweet potato and sugar sorghum – barely changes crop structure. The optimal area of sweet potato is firmly 120 hectares, the remaining area is occupied by the sugar sorghum. Beside given resources the quantity – and so the revenue do not increase above 528 hectares. According to indices calculated on the basis of bio-ethanol per hectare and area need for producing one liter of bio-ethanol efficiency decreases with area increase.

If we limit the sowing area of sweet potato and sugar sorghum to 10-10%, then other plants also get place in the optimal production structure however the maximum extractable quantity of bio-ethanol can be 1 322 459 liters.

At this run I received shadow price for human labour force in July and October and also for the 3rd period of the 3rd machine.

In case we change the capacity of human labour force simultaneously in July and October the crop structure changes significantly and so the quantity of producible bio-ethanol.

In case of bio-ethanol-purpose production efficiency decreases with increase of human labour force capacity because those plants can also be involved into the optimal crop structure which use this resource less efficiently.

3.4. The generalized "Copyright" version of the model

During my research – for possible sale – I prepared the copyright version of the model in CD format. The basic model can be found on the CD which is practically a database about plants coming into question concerning energy-purpose biomass production, with general basic technical parameters, recommended condition system, recommended target functions – which can be adjusted to the parameters of a given company.

The system can be operated with WINQSB software (simplified by myself) used in Operational Research subject. For usage the knowledge of basic principles of Windows-based computer programs is sufficient. Learning this is simple, the sufficient fundamentals can be easily acquired for unaccustomed users in computer science.

I reckon that usage of the CD can significantly help efficiency of planning. Uploading data of the given company plan-versions can be made fast and easy.

3.5. New and recent scientific results

1. Using appliances of mathematical programming **I set up a model** which gives an opportunity for agricultural ventures to make model calculations that are relatively simple but can be operated by simulation. For the sake of generalization I intended to prepare such a model **which can also demonstrate optimization for biogas, bio-ethanol and bio-diesel end-products**. The major question of the decision is that beside the available area and resource capacity is it worth producing for food-purpose or rather energetic-purpose production. **The optimization model of biomass production is based on linear programming** and makes possible to determine the optimal crop structure in reference to a chosen agricultural area in case of different target functions.

2. I executed concrete calculations at the sample farm during which I raced food-purpose and energetic-purpose plant production branches and proved that **beside a given condition system among energetic plants production of those plants**

which are suitable for bio-ethanol production is competitive in proportion to food production. Regarding the value of the target function a relatively high additional result came out in case of maximization of the target function of ethanol production, if I have not put the technologic – crop rotation requirements for sugar sorghum and sweet potato. Limiting the area of these two plants because of agro-technical causes the value of the target function is 16.5% higher than the basic version.

3. With reference to the model farm **I prognosticated the achievable profit mass** in case of bio-gas production. I found that if in case of optimization for food-purpose production we take the value of the target function 100% then bio-gas production from the main product reaches only a small fragment – 15.6% - that of food- and feed-purpose production. This means that **for bio-gas production it is worthy to use byproduct, the main product should be sold for food or feed-purposes**.

4. **By means of the prepared model I executed sensibility tests.** According to this, I studied how the change of input-output prices affect the production structure, how the competitive position of certain bio-energetic end-products depends on the change of resource capacity, moreover how the optimal crop structure and achievable maximum profit is influenced if the quantity of available area, labour force, chemical fertilizer and machine capacity increases or decreases and due to this change **how efficiency and demand indices change in case of biogas, bio-ethanol and bio-diesel production**.

5. **I generalized the company optimization model prepared for biomass production**, in such a way that it gives suitable decision preparation information for any kind of agricultural companies in relation to building biomass into the production structure. The generalized model is ready for use in "Copyright" format – namely **a marketable research result was born during my research**.

4. CONCLUSIONS AND RECOMMENDATIONS

Basically two factors influence the market of bio-fuels. The first is the world market price of crude oil, the second is environmental pollution and the development of environmental awareness of the population on the impact of natural disasters. The constantly increasing tendency of crude oil price reached that value where production and market of bio-fuels among which bio-ethanol could become profitable.

Search of alternative – first of all the renewable – energy resources is a professional, economic and social interest all over the world of top-notch research. However nowadays production of energetic-purpose plants is an environmental-economic-social risky process far exceeding the general level, enhancing safety of energy supply (import diminution), long-term cover of resident population's living all makes continuation of research reasonable.

Recently significant changes took place in domestic land use. The rate of uncultivated forest and agricultural land got higher. Wasting land do not seem to be a proper method in resource management, utilization and cultivation of these lands is necessary. In Hungary there are also many agricultural family farms which consider the possibility of producing plants for bio-energetic purposes in order to reach higher profit. Nowadays it is already realistic to found an agricultural energy producing venture. The aims are feasible however reaching them necessitates maintenance of present state subsidies and increase of investment credits and non-refundable subsidies.

Bio-energetic investments thus are by all means have to be dealt with. First of all energy buy-off of plants should be aimed with such complex investments which strengthen the competitiveness of basic activities. All over the world people strive for the improvement of agricultural production's structure and make it competitive and search for possible channels. Involvement of bio-energetic-purpose production into the production structure is among these. International experiences show that mathematical programming models can be well applied for handling the problem and determining realistic orientations. Those type of models can be principally applied which consider agricultural production peculiarities.

The model prepared for optimization of biomass production can be suitable for farmers to make such economic analyses within their own scopes – on company level – which can evaluate technologies applied among the given ecologic facilities, specific expenditures and achievable market prices in the framework of a single model on a complex way.

Application of the model can be also of great importance for agricultural entrepreneurs because it forces them to cast an account, to check the applied technology (in relation to ecologic facilities), specific expenditures, demand indices, achievable market prices, etc., thus it inspires and forces them for innovative thinking.

PUBLICATION LIST

Academic book, book detail

1. I. Szűcs (ed.) - **É. Bedéné Szőke -** M. Farkasné Fekete - J. Molnár - Zs. Széles - K. Takácsné György - I. Takács - J. Vas: Birtokviszonyok és mérethatékonyság (Tenures and size efficiency.) ISBN 963-502-782-6. Agroinform 2003. Budapest. pp. 224.

2. **É. Bedéné Szőke** - Zs. Mohamed - Gy. Ugrósdy - I.K. Zakor: A hatékonyság vizsgálata a Náxosz-nál (Efficiency examination at Náxosz) - In I. Szűcs - M. Farkasné Fekete: Hatékonyság a mezőgazdaságban (Efficiency in agriculture). ISBN: 978-963-502-889-4 Agroinform. 2008. Budapest. pp. 343.

Scientific journals

Scientific article published in Hungarian

1. K. Tóthné Lőkös - **É. Bedéné Szőke -** Gy. Gábrielné Tőzsér: EU országok összehasonlítása néhány makroökonómiai mutató alapján (Comparison of EU states on the basis of some macro-economic indices). ISSN 1586-4502, Bulletin of the Szent István University, 2008. Gödöllő, pp. 101-111.

2. **É. Bedéné Szőke -** Zs. Mohamed**:** Energianövények szántóföldi termelésének optimalizálása (Optimization of energy-crop growing). Gazdálkodás, 2010. 54. évfolyam, 04. szám, pp. 389-396.

Scientific article published in English

1. Zs. Mohamed - Sz. Takács - I. Szűcs - **É. Bedéné Szőke:** Effect of agricultural research and development on the GDP of EU member states. Gazdálkodás, 2010. 54. évfolyam, 24. különszám, pp. 2-15.

2. **É. Bedéné Szőke** - Zs. Mohamed - Sz. Takács: The mathematical modelling of energy-plant production. Economics of sustainable agriculture. 2010. Szent István University, Gödöllő, ISBN 978-973-269-145-9, pp. 193-204.

Lectures on scientific conferences

Hungarian

1. L. Szelényi - **É. Bedéné Szőke:** A gazdasági változások regionális vizsgálata ökonometriai módszerekkel (Regional study of economic changes by econometric methods). Rural development section ISBN 963 9256 75 7 ISBN 963 9256 88 9. 8th International Agro-economic Scientific Days, 26-27th March 2002. SZIU Economics and Agricultre College Faculty Gyöngyös. pp.311-315.

2. L. Szelényi - **É. Bedéné Szőke:** Többváltozós térségi vizsgálatok (Multivariate regional studies). Agro-economic section ISSN 0237-9902. 29th Óvár Scientific Days, 3-4th October 2002. West-Hungarian University Agricultural and Food Science Faculty, Mosonmagyaróvár. pp. 204.
3. L. Szelényi - **É. Bedéné Szőke:** Térségi klaszterek (Regional clusters). Economics, organization section. ISBN 963-9483-02-8 3rd Alföld Scientific Land management Days, 17-18th October 2002. Tessedik Sámuel College Mezőtúr. pp. 127-132.
4. L. Szelényi - **É. Bedéné Szőke -** F. Ruff: A vidékfejlesztés helyzetének többváltozós elemzése (Multivariate analysis of rural development situation). Economic analysis section. ISBN: 963-472-721-2. Agrárgazdaság, Vidékfejlesztés és Agrárinformatika az évezred küszöbén /AVA nemzetközi konferencia (Agricultural Economics, Rural Development and Agricultural Informatics on the edge of the millennium International Conference) 1-2nd April 2003. Debrecen University Agricultural Sciences Centre, Debrecen. pp. 268.
5. L. Szelényi - F. Ruff **- É. Bedéné Szőke:** Környezetvédelmi mutatók többváltozós elemzése (Multivariate analysis of environment protection indices). Environmental management section., ISBN 963-214-313-2. 9th International Agriculural Economics Scientific Days 25-26th March 2004. Károly Róbert College, Gyöngyös. pp. 79.
6. L. Szelényi - **É. Bedéné Szőke** - F. Ruff - Sz. Vinogradov: Agrárökonómiai elemzések többváltozós módszerekkel (Agricultural economic analyses with multivariate methods) 30th Óvár Scientific Days. Economic informatics section. West-Hungarian University Agricultural and Food Science Faculty, Mosonmagyaróvár. 7th October 2004. Conference CD:aokonomia\Szelenyi.pdf.
7. T. Szakács - **É. Bedéné Szőke** - M. Farkasné Fekete - L. Szűcs - I. Szűcs: Lehetséges célfüggvények a magyar bioenergetikai modellhez (Possible target functions for the Hungarian bio-energetic model). 11th International Scientific Days 27-28th March 2008. Károly Róbert College, Gyöngyös ISBN 978-963-87831-1-0, pp. 261-268.
8. **É. Bedéné Szőke -** Zs. Mohamed - I. Szűcs**:** A termőföld hasznosításának alternatív lehetőségei. (Alternative prospects of land-use) ISBN 978-963-9883-30-7. Ingatlanvagyon-Gazdálkodási és Ingatlan-Forgalmazási Konferencia (Conference of Immovable property-Economics and Immovable Dealing), 8-9th June 2009. West-Hungarian University Geoinformatic Faculty, Székesfehérvár. pp.211-213.
9. **É. Bedéné Szőke -** Zs. Mohamed - E. Pallás - I. Szűcs: A kutatási tevékenység hatékonyságának mérési lehetősége. (Measurability of research efficiency) ISBN 978-963-7294-74-7, 5th Erdei Ferenc Scientific Conference, 3-4th September 2009. Kecskemét College, Kecskemét, pp.23-27.

English

1. K. Tóth-Lőkös **- É. Bede-Szőke -** I. Szűcs **-** Gy. Gábriel-Tőzsér: An alternative method for grouping regions from agricultural aspect. Measuring Sustainable Agriculture Indicators - Third International Conference on Agricultural Statistics – 2-4th November 2004, Cancun, Mexico, www.nass.asda.gov/mexsai
2. K. Lőkös Tóth - **É. Szőke Bede -** J. Vas: Regional Differentiation Analyses On NUT-1 Level. ISSN 1539-8757, Economics Session - Applied Business Research Conference, 2-6th January 2006, Orlando, Florida, USA, pp.7.
3. I. Szűcs - É. Zs. Járási - **É. Szőke Bede** - Gy. Tőzsér Gábriel: Destiny and Earnings of Research's Results. VII. Alps-Adria Scientific Workshop 28th April – 2nd May, 2008, Stara Lesna, Slovakia – Volume 36 (2008) Cereal Research Communications, pp. 1983.
4. **É. Bedéné Szőke -** Zs. Mohamed - E. Pallás - Sz. Takács**:** Programming model suitable for economic underlying of specialization of agricultural entrepreneurs to biomass production. 8th International Conference on Applied Informatics. ISBN 978-963-9894-72-3 Eszterházy Károly College, Eger, Hungary, 27-30th January 2010. pp. 791-793.
5. **É. Bedéné Szőke -** Zs. Mohamed - E. Pallás - Sz. Takács**:** Optimization of biomass production on company level. 8th International Conference on Applied Informatics. ISBN 978-963-9894-72-3 Eszterházy Károly College, Eger, Hungary, 27-30th January 2010, pp. 583-593.

University notes and details

K. Tóthné Lőkös - I. Szűcs - Gy. Gábrielné Tőzsér - **É. Bedéné Szőke** - L. Felleg - Gy. Ugrósdy: Összefüggés vizsgálatok (Coherence analyses). University note. SZIE GTK 2011. pp. 99

Research activities

2006-2009.	BIOENKRF Project 5.2 Research topic: The complex economic analysis of operating bioreactor, determining the system conditions (border points), its' coherencies with in- and output characteristics and reversibility. Supervisor: Dr. István Szűcs.
2003-2005.	Analysis of regional differentiation in the light of sub-regional indices. OTKA. Supervisor: Klára Tóthné Dr. Lőkös.
2003-2004.	Working out of programming models and production functions helping prognostication of agricultural economics. OKTK. Supervisor: Dr. László Szelényi.
2003-2004.	Professional and institutional consolidation of environmental protection planning and programming. KAC, Supervisor: Dr. László Szelényi.
2000-2002.	EU-conform regulation of land property and usage orientating to agricultural plant criteria-system. FVM. Supervisor: Dr. István Szűcs.
1998-2000.	Preparation of impoundment of regions with unfavorable characteristics. FVM, Supervisor: Dr. Szűcs István.