University doctoral (PhD) dissertation abstract

ECONOMIC ANALYSIS OF CERTAIN ENERGY CROPS AND THEIR EFFECT ON LAND-USE

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1. INTRODUCTION AND OBJECTIVES

At present it is often heard more and more about the utilization of renewable energy sources and their domestic and international possibilities. In the last two decades people have been getting interested in the way to decrease or at least keep the quantity of pollutants on the same level. To solve this problem, the Kyoto Protocol was signed at the end of 90's which earmarked 5.2 percent decrease of the greenhouse gases for the period 2008-2012. Parallel to this, the White Paper, which was made by the European Union, determined the rate of renewable energy sources to 12% by 2010, while the quantity of liquid biofuels to be produced to 5 million tons. According to the forecasts of the Union, the increase of the rate of biomass would decrease the quantity of carbon-dioxide in the atmosphere by 205-210 million tons, and our energy import dependence would temper from 48 to 42 percent.

It can be seen from the foregoing that the utilization of solar and biomass energy becomes of major importance, i.e. the increase in the rate of renewable energy sources can be higher compared to the other energy sources.

To fulfill the aims of the Kyoto Protocol, the participating countries developed a quota system. Our country - along with the other member states - got a specific emission quota of which the government distributed to the industries when the Protocol took effect. This quota is not allowed to be exceeded by the industries. In those countries where the emission was high, quota commerce evolved that led to the growth of quota prices. This made necessary the upgrading and closing of the old coal and hydrocarbon plants. The more and more costly establishment of upgrading and the more and more difficult maintenance of the operating plants induce the extension of alternative energy sources' use. Under the alternative energy sources we mean those from which we can extract thermal, mechanical, and electrical energy as a supplement to the current hydrocarbons. A group of these is the continuously reproducing, so-called alternative - renewable - energy sources, among which the best known are solar, wind, hydro, geothermal energy and biomass. Among the previously mentioned in Hungary biomass is paramount – as one of the most important renewable energy source – which is suitable for producing thermal, electrical energy, as well as fro fuel.

We can differentiate materials suitable for solid (woody and herbaceous energy plantations), liquid (bioethanol, biodiesel) and gas (biogas) energy production. Currently, the country's renewable energy use is mostly biomass-based (91.7%), and this percentage will continue to grow.

In my dissertation my general objective was to analyze the long term profitability and competitiveness of the mostly used conventional arable crops produced for energy extraction and the woody energy plants that are not widely used in Hungary. For the analysis I apply and improve models and analyzing methods that were successfully used in other fields, which can be effective tools for basing the decisions of rational land-use by renewable biomass sources.

My objectives can be grouped into four sections:

1. Presenting the significance of conventional arable crops suitable for energy extraction and woody energy crops in land use in Hungary and in the Northern Great Plain region

Hungary's arable, agro-ecological potential is outstanding in European comparison as well, however, its spatial distribution can be considered as heterogeneous. This heterogeneity is not reflected by the range of recently produced arable crops, since there are five crops on 80 percent of the field: corn, wheat, sunflower, colza and barley. 10-15% of the country's arable land is less-favored. My aim is to present the role of arable crops used in bioethanol and biodiesel production and woody energy crops as solid fuel in land use and energy supply at present and in the future.

2. Comparative analysis of the economics of arable crops and energy plantations

The farmers are reluctant to produce any crops that are unknown to them, and can count with yield only every second or third year and furthermore the initial cost is high as well. Woody energy crops can also be considered as such cultures. On the less-favored areas the production level and the profitability of the operation is lower, on the other hand by the reduction of livestock the opportunities for domestic use of cereals is also narrowed. In favorable vintages surpluses can accumulate, and the farming and market risk also increase. A good solution for this can be the energy utilization of biomass and the long term expansion of woody energy crops. In my dissertation I made the comparative analysis of conventional arable crops and woody energy crops by nominal calculations. I present the return of the plantations by investment economics indices.

3. Long-term land-use models and the analysis of the enterprises' competitiveness

The crop structure of conventional arable crops which are the basis for bioethanol and biodiesel production can be modeled on annual or medium term, while the woody energy crops' lifespan is 12-16 years. Consequently, for the analysis of competitiveness simultaneous dynamic linear programming must be applied, by which the characteristics of plantations can be also considered. This model promotes the sound decision-making for field of different natural endowments and the analysis of the enterprises' competitiveness as well.

The summary of used databases, activities and outputs of the research are shown in Figure 1.

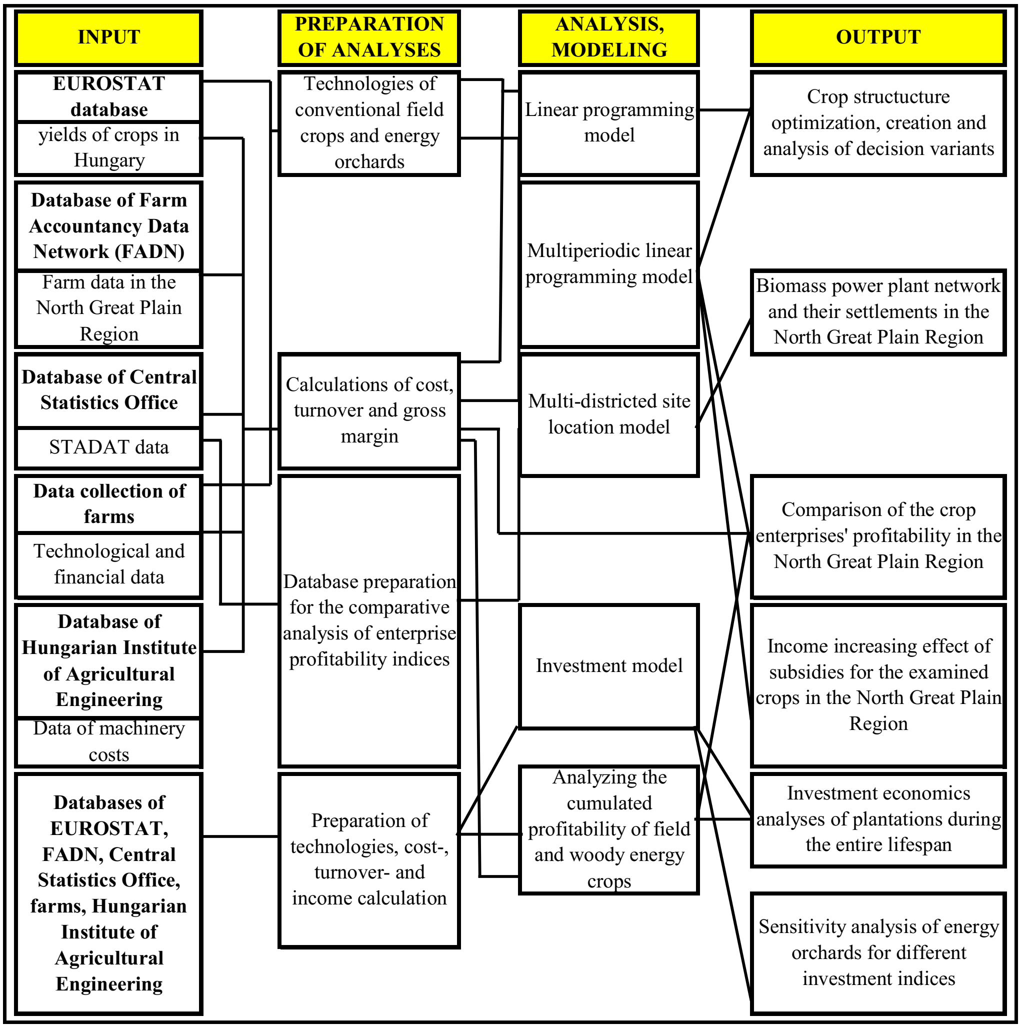

Figure 1. Research objectives, inputs and activities

Source: Own assembly

2. BACKGROUND OF THE RESEARCH AND THE APPLIED METHODS

2.1. Background of the research

I have chosen my research topic in 2005, when I have started to deal with decision support system in crop production. In my diploma work I optimized the crop structure of a cooperative in Hajdúszoboszló.
When I determined my research topic I aimed to fit into to the doctoral program of Ihrig Károly Doctoral School of Management and Business Administration and to join to the scientific work in the Department of Economic Analysis and Statistics.

2.2. Material of the research and the applied methods

To reach the aims drafted in the introduction extensive data collection was required. For the analysis of the long time series of land-use I applied the databases of Hungarian Central Statistical Office, Research Institute of Agricultural Economics, and Statistical Office of the European Communities (EUROSTAT). Despite the fact that it contains estimate in several places I also applied the electronically available database of FAO (Food and Agricultural Organizations of the United Nations).

I used the data of Central Agricultural Office and Ministry of Rural Development for the economics analysis.

For the analysis of the northern Great Plain region the database emerged from the Research Institute of Agricultural Economics and the data of a cooperative from 2008 to 2010 that plays a decisive role in bioenergy production in the region.

In the course of my research I used the technological, production, cost, and income data from practice and also the subsidies and grants of the enterprises. The basic data of enterprise technologies needed for the simulation model was based on own data collection:

- I have collected data from 16 agricultural undertakings from 2004 which have medium endowments. From these 7 are located in Hajdú-Bihar county, 4 in Szabolcs-Szatmár-Bereg county, and 5 in Jász-Nagykun-Szolnok county.

- I prepared the arable crop production technologies based on the questionnaires of production managers and interviews with key enterprise managers.

For the calculation of machinery costs beside my own data collection I used the summary data of Hungarian Institute of Agricultural Engineering (*GOCKLER, 2010*).

Based on the data of 2009 I performed investment economics calculations for the long term planning of orchards. For determining the calculative interest rate needed for the calculation of present value I considered the long term government bonds' interests (market reference yield) as being risk-free. According to this, and on the basis of the market reference yield of 2008-2009 government bond of Hungarian Treasury, I made calculations with 7.5% calculative interest rate. The credit interest was used according to the interest rate of the Hungarian National Bank, which was 10%, while the corporate tax rate is 18%.

I analyzed the profitability and competitiveness of energy crops with profit calculations and market analyses. I created a multi-periodic crop structure model which considers the existing enterprise resources, technologies to determine the optimal production structure and the maximum income of the entire period. I tried to prepare this model in a way to reflect the reality as well as possible and to be easily manageable from the point of mathematics and informatics as well.

3. MAIN FINDINGS OF THE DISSERTATION

In the first part of my dissertation I analyzed the significance of conventional arable crops suitable for energy extraction and woody energy crops in land use in Hungary and in the northern Great Plain region. After this I compared the economics of arable crops and energy plantations with nominal and dynamic calculations and I made the investment economics calculations of energy orchards. In the next section I examined the long term land-use modeling and the competitiveness of enterprises in the interval of 12 years. At last I prepared a crop structure plan that considers the market and production risk of energy production from biomass under different support conditions.

3.1. Presentation of the significance of conventional arable crops suitable for energy extraction and woody energy crops in land use in Hungary and in the northern Great Plain region

In the agriculture of our country the lands' use, cultivation and preservation are of great importance (*MAGDA, 2007*), therefore, such a land use system must be striven which fits best to the environmental endowments and bounds. The fact must be taken into account that the reduction of livestock from 2004 until now has resulted in major changes in land-use, so new opportunities are to be sought in the agricultural production. To the known use forms - food and feed materials production, pharmaceutical production, industrial raw material production, recreation services, nature conservation, environment maintenance – a new alternative way can be classified which name is energy raw material production (*MAGDA-GERGELY, 2006*). This means that such a land-use system is to be created that maximizes the use of endowments in the soil, thus reduces our dependence on energy. To reach this, the first step can be the introduction of a different land-use method which adapts to the modern needs. It is possible to plant woody energy crops with the association of other activities; to establish an intensive horticultural production; and to do other agricultural production for energy purposes which is established to supply the local needs (crèche, nursery school, school, local authority, residential houses, etc.). Besides, on those lands where arable production cannot or can hardly be done, green-energy use is justified, which further reduces the dependence on energy due to the limited available energy sources (oil, natural gas).

Since both Hungary's and the Northern Great Plain region's land endowment is good, energy dependence is high, therefore, it is allowable to deal with energy crops beside producing to the domestic and export markets which can be considered as available. In the conventional arable crop production the corn, winter wheat, sunflower, and winter colza are of great significance in the energy production. The above listed cereals play an important role in bioethanol production and the oil crops are suitable for producing biodiesel. Beside the agricultural main products, the by-products can have a paramount significance in the extraction of energy, which are the field wastes generated during production. Timber wastes are also classified into this group – bark, chips, sawdust –, cast-off wooden furniture and paneling. Currently, only 30-40% of agricultural by-products are used for energy production.

Examining the by-products of Northern Great Plain region I found that the quantity of wood wastes, trimmings from fruit, vine production and forestry is the most significant in Szabolcs-Szatmár-Bereg county (101,288 tons), then follows Hajdú-Bihar county (51,673 tons) and Jász-Nagykun-Szolnok county (27,465 tons), from which a total of 22.62 MWh energy could be produced by biomass-based power plants. If this quantity was used for energy production we could supply in Szabolcs-Szatmár-Bereg county 4, in Hajdú-Bihar county 2 and in Jász-Nagykun-Szolnok county 1 chips-based regional energy-producing power plant (Table 1.). Among the advised centers, in the county of Szabolcs-Szatmár-Bereg in Piricse one power plant has already been established.

Table 1. The energy utilization potential of cuttings in the northern Great Plain region

Center	Demand (tonna)	Capacity (MWh)
Szabolcs-Szatmár-Bereg megye		
Jánd	32 969	4,06
Levelek	31 951	4,01
Nyíregyháza	12 315	1,51
Piricse	24 053	3,09
Hajdú-Bihar megye		
Debrecen	32 969	4,06
Nagyhegyes	31 951	4,01
Jász-Nagykun-Szolnok megye		
Tiszapüspöki	27 466	3,63

Source: Own calculation

If the energy potential of mainly cereal straw from arable crop production is examined in the region a much higher potential is gotten. This is underpinned by the fact that in the three counties of the region the ratio of arable land-use is remarkable.

Table 2. shows that according to the existing materials in Szabolcs-Szatmár-Bereg county 4 centers, in Hajdú-Bihar county 8 centers and in Jász-Nagykun-Szolnok county 10 bale-based power plant are to be established. Each power plant’s capacity is 3 MWh.

Table 2. The energy utilization potential of arable residues in the northern Great Plain region

Center	Demand (tonna)	Capacity (MWh)	Center	Demand (tonna)	Capacity (MWh)
Szabolcs-Szatmár-Bereg megye			**Jász-Nagykun-Szolnok megye**		
Tunyogmatolcs	26 893	4,47	**Szolnok**	15 355	3,35
Ajak	17 997	3	**Törökszentmiklós**	14 622	2,39
Kállósemjén	18 207	3,02	**Kisújszállás**	25 468	4,18
Nyíregyháza	22 401	3,71	**Jászberény**	18 926	3,09
Hajdú-Bihar megye			**Tiszasüly**	12 214	2,02
Mikepércs	16 235	4,5	**Jászalsószentgyörgy**	21 817	3,57
Folyás	29 075	3,2	**Mezőtúr**	12 214	3
Kaba	12 755	2,11	**Mezőhék**	12 214	2,38
Báránd	21 857	2	**Cserkeszőlő**	12 482	2,27
Bojt	12 755	3,76	**Tiszaszentimre**	23 759	3,89
Komádi	26 059	0,89			
Vámospércs	15 870	3,38			
Kismarján	12 755	3,4			

Source: Own calculation

At the planning of the centers I calculated with the existing raw materials and maximized the distances.

In summary, I concluded that the by-products, stalk residues from arable crop production mean the main potential of alternative (waste) biomass utilization in the Northern Great Plain region. In Szabolcs-Szatmár-Bereg county the wood wastes from fruit and vine production and forestry are also remarkable and rationally useable. In the future the short rotation woody energy plants can mean a further opportunity especially on the less-favored wet or sandy soils.

Beyond the conventional arable crop production the significance of woody energy orchards is higher and higher in Hungary. This is due to the areas getting out of agricultural food production that can be well utilized. The present spatial distribution of the planned energy orchards is uneven (Figure 2.), since almost 30 percent of the permitted orchards are located in Baranya, 20 percent of it in Somogy county, and the remaining 50 percent belong to the other counties.

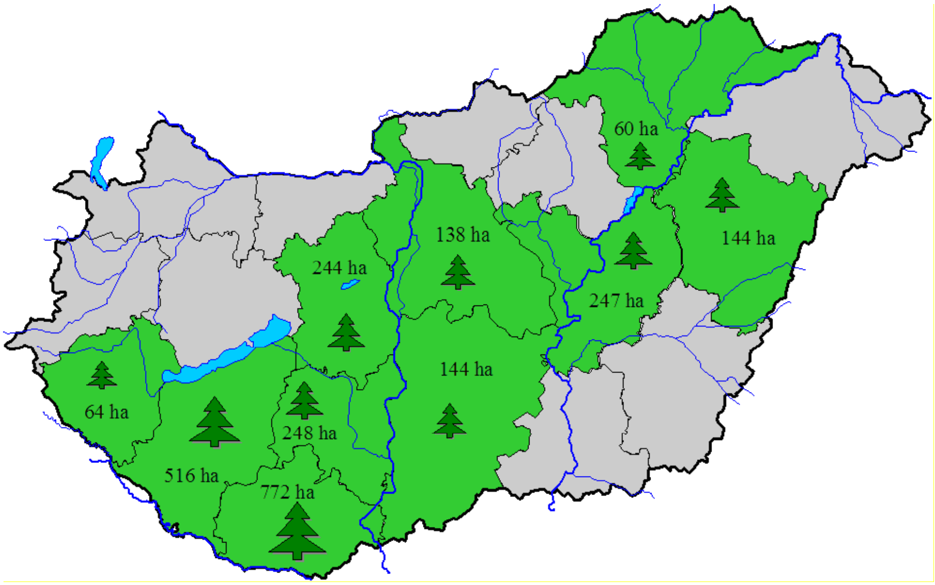

Figure 2. Spatial distribution of the permitted woody energy orchards by counties in 2009 in Hungary

Source: Own construction

Tolna county is also remarkable with its 10 percent share. Considering the plantation areas slightly more than half of the planted orchards have been established on maximum 10 hectares large, continuous territorial units.

Analyzing the present subsidy requests, according to the forecasts about 6-7 thousand hectare energy orchard can appear on the market, and three-quarter of it will be woody energy plantation.

However, regarding the plantation data so far, in Hungary approximately with 200-230 hectare energy orchard can be counted by 2030. The energy raw materials from woody energy orchards require the building of several regional biomass plants in the future. In my opinion, however, the building of biomass plants can only be realized in our country if the government manages the problems of agriculture, rural development and environment protection jointly, which assumption is the coordinated work of various ministries as well.

3.2. Comparative analysis of the economics of arable crops and energy plantations

In order to be able to compare the economics of conventional arable crops and woody energy orchards I made cost and outcome calculations for the cultures.

Knowing the cost and turnover data I calculated the gross margin value. The planned gross margin with taking the subsidy into account in nominal value is summarized in Table 3.

Table 3. Gross margins of the conventional arable crops and woody energy orchards for one hectare with subsidies in the examined years

Unit of measurement: Ft/ha

Year/Plant	Corn	Turnsole	Winter wheat	Colza	Locust	Poplar	Swedish willow
1st year	137 806	81 789	115 748	114 267	- 96 988	- 54 236	- 113 429
2nd year	140 713	82 078	118 052	116 818	6 025	208 573	- 163
3rd year	143 668	82 298	120 406	119 450	384 968	- 31 061	406 197
4th year	146 670	82 437	122 806	122 163	- 31 715	322 474	- 1 267
5th year	149 713	82 489	125 253	124 960	39 803	- 41 152	39 803
6th year	152 794	82 441	127 743	127 840	501 579	349 731	525 813
7th year	155 908	82 283	130 274	130 805	- 61 190	- 52 122	- 10 602
8th year	159 048	82 004	132 843	133 855	38 313	379 669	38 313
9th year	162 209	81 589	135 446	136 992	570 482	- 64 447	598 408
10th year	165 383	81 026	138 080	140 215	- 81 971	412 548	- 21 719
11th year	168 563	80 299	140 741	143 524	36 539	- 78 296	36 539
12th year	171 739	79 392	143 422	146 919	649 739	448 654	681 915

Source: Own calculation

The nominal calculations of the annual average gross margin for one hectare with subsidy for the interval of 12 years gave the following sequence: willow, locust, corn, poplar, colza, wheat, sunflower (Figure 3.).

After this I examined the gross margin increasing effect of subsidies, and I concluded that it is very high at the sunflower among the conventional arable cultures, because it is over 100%. It is lower in cases of wheat and colza, their value is about 58%. The lowest value has the corn (44.5%).

On the basis of the results of woody energy orchards greater significance cannot be detected (Table 4.).

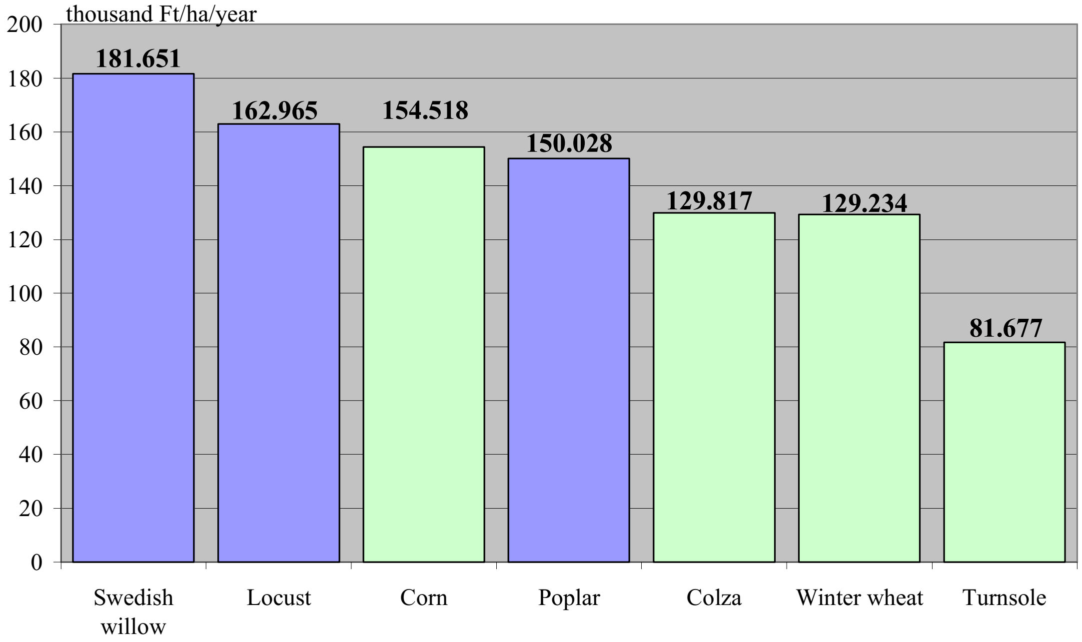

Figure 3. Available annual gross margins of the conventional arable crops and woody energy orchards during the examined 12 years
Source: Own calculation

Table 4. Income increasing effect of subsidies for the examined crops

Unit of measurement: %

Plant				**Wood speciest**		
Corn	Winter wheat	Turnsole	Colza	Locust	Poplar	Swedish willow
44,5%	58,3%	139,7%	57,9%	57,8%	59,4%	50,5%

Source: Own calculation

Since according to the average gross margin values in the sequence the energy crops are in the first three places, I considered to be important to analyze their investment economics. The calculations were executed (without equity) with only taking only the single area payment into consideration, with single area payment and the available plantation grant of the first year, and without considering any subsidies as well.

Without plantation grant, according to the analysed four investment economics indices the investment on all three energy orchards can be considered as favourable, and it is worth to deal with them on a longer term. The investment returns for 6th year in cases of locust and willow, and the poplar's for 4th year (i.e. for 2nd harvest). The return of the invested capital is 3.99 for poplar, 3.34 for locust and 3.21 for willow on the basis of profitability index. It can be stated that by the end of the investment, i.e. by the 12th year in case of 10% credit interest and 7.5% discount interest rate, poplar will have the highest NPV value (833,682 Ft). This means that in present value we will have with 833,682 Ft more income compared to that case when we would invest the amount of plantation for 12 years into stocks at 7.5% interest. For willow, the net profit discounted for the starting date of the investment is 799,009 Ft during 12 years. Among the examined orchards, locust is on the third place (775,645 Ft).

When the ***plantation grant was also taken into account*** the highest NPV was reached by willow after 12 years with 10% credit interest and 7.5% discount interest rate (1,145,474 Ft). Financially, the willow is followed by locust (1,107,754 Ft) and then poplar (1,062,723 Ft).

The value of internal rate of return is high for both three orchards because of the single premium in the first year. The locust's is 65%, the willow's is 57%, which is almost 2.5 than of the values without plantation grant. The same value is obtained almost 3 than of the values without plantation grant. From financial aspect both plantation can be suggested according to the values of IRR, because these are higher than the yield of alternative investments with similar risk.

According to PI the investment returns 5.89 for poplar, 5.86 for locust and 5.7 times for willow during the entire period.

After having made the analyses without equity, a ***sensitivity analysis*** was made for the four investment economics indices with the consideration of single area payment. I analyzed what effects the changes in the parameter values of key importance (credit interest, maximum amount of credit, calculative interest rate) have on the net present value, internal interest rate, profitability index and the return on time of the investment.

From the calculations I would like to emphasize the net present value (NPV). At the sensitivity analysis for NPV I took account the various combinations of credit interest and loan. The decrease in the amount of equity generates a significant NPV fall for both three plants. At 10% credit interest it is 18% for poplar and about 30% in case of locust and willow, so considering the economy of the investment the existence of equity is of great significance for the last two plants. The growth of credit interest means a more detectable NPV decrease in cases of higher loans.

Further analyses were made for Swedish willow and locust. Assuming no equity for the locust investment the IRR-value is higher, for the willow investment the NPV-value is higher than the credit interest of 8%. The dotted line shows the locust investment, the dashed line the willow's net present value by different credit interests (Figure 4.). The IRR index of locust is 25%, of the willow is 23%. It can be seen that for the willow investment the values of IRR are higher until the credit interest is under 11.8 percent.

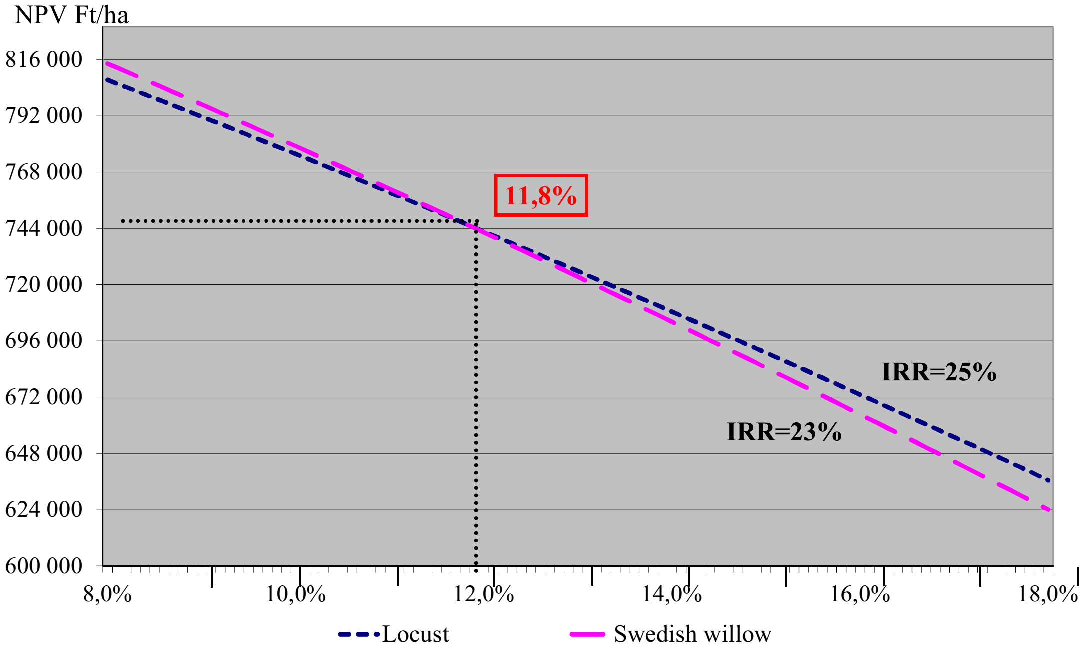

Figure 4. Net present value and internal rate of return for the three energy crops
Source: Own calculation

Therefore I state that the value of IRR is misleading, because although the total turnover from the investment is higher, but it appears later. That is why if the locust's discounted rate is lower the willow's NPV is higher and vice versa. If one should choose from the investment of locust and willow, according to the actual credit interest, the willow is worth to be chosen over 12.9% interest rate and below this rate the locust is more competitive financially. Certainly, this is rather theoretical, since the production site need of these two crops is different.

In the sensitivity analysis at the examination of return period beside the change of loan and discount rate I analyzed the return on time. In case of plants to be harvested in every three year (locust, willow) the return on time is 6 years or 9 years during the examined 12 years. The return of Swedish willow at 12% discount interest rate changes to 9 years and the locust's at 12%. Below these interest rates the return is 6 years. The two-year-harvested poplar's investment returns for the fourth year until 10% interest rate and over it for the sixth year. This means that we have to calculate with lower risk for the poplar, since the orchard returns faster, so we can produce profit sooner compared to the other two plants.

For the analysis of profitability index in the sensitivity analysis we used the different variations of the amount of loan and interest rate. At all of the examined combinations the investment is realizable, since even the least PI value is 3.21. Examining a given loan we can see that the higher is the value of 'r' the less is the value of PI. The investment returns three times with locust and willow at 8-10% credit interest, and twice at between 8-12% interest rate during the examined period. The invested cash-flow on poplar orchard returns three times at 8% interest rate, twice at 10-12%.

3.3. Long-term land-use models and the analysis of the enterprises' competitiveness

In the previous two sub-chapters I compared the enterprises by nominal and dynamic profitability calculations. The sequence of the enterprise analyses can be influenced by the given resources of the farm and the external environment as well.

In this chapter the advantages and necessity of the systematic analysis will be presented through the modeling of a 500 hectare sample farm with mixed soil conditions. The ratio of various soil types was given by the data of an existing venture. Thus, the size of the seasonally flooded area is maximum 100 ha, which limits the willow's area. On the other regions all cultures can be produced. In cases of sunflower and colza I gave a 5-year crop rotation constraint and ruled out the possibility of corn monoculture. The maximum area size of wheat can be 300 hectares; the locust's maximum is 200 hectares.

In the analysis I created three model types: a linear programming model which objective function coefficient value contains only the area payment (LP_T); a linear programming model in which the normative area payment and the plantation grant for the woody energy crops in the first year (LP_TT); a linear programming model in which no subsidy is required (LP_TN).

After solving the models I got a crop structure which is independent from subsidies, i.e. the subsidies do not affect the competitive position of the respective cultures. The production structure is shown in Figure 5. In the first year, except the sunflower, all crops got into the production structure. The largest ratio had the energy crops (app. 46%), and these are followed by cereals (42%), and then winter colza with 12%.

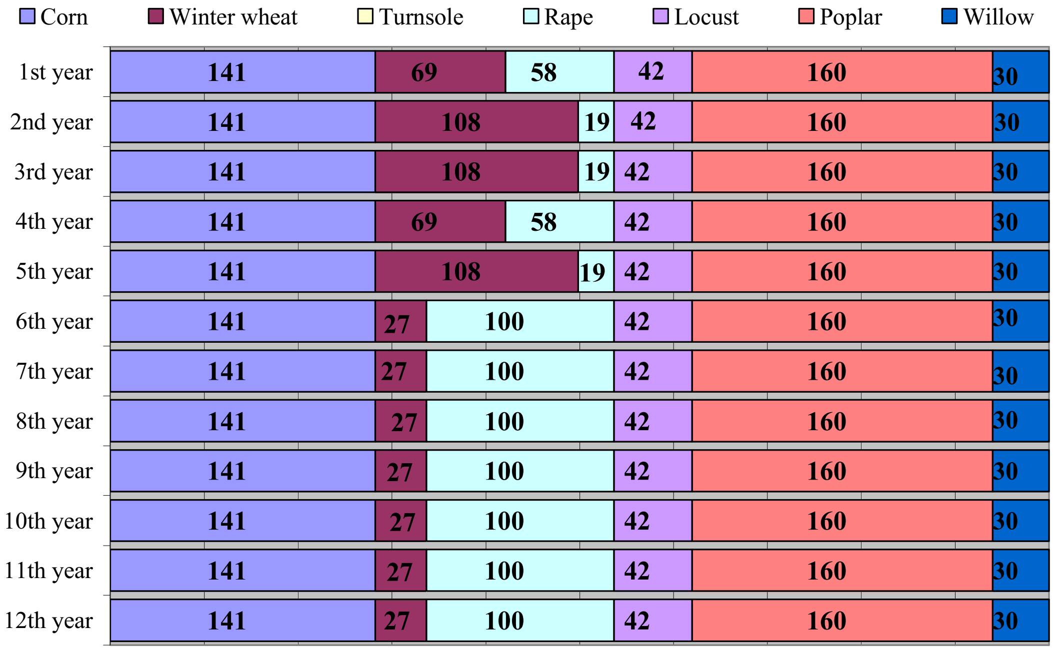

Figure 5. The linear programming model which contains only the area payment (LP_T) for the examined 12 years*

* This production structure is the same as the non-supported model (LP_TN), and as the one with plantation grant (LP_TT)

In year 2, 3, 5 the rate of cereals is about 50% within the entire crop structure, and parallel to this the ratio of colza reduces to 4%. The role of energy crops in the production structure does not change, since with a given plantation the area is immobilized for the entire period.

From 6th year there is a larger change going on compared to year 5. The rate of cereals reduces from 42% to 34%, and in contrast, the colza area size increases to 20%.

With the ***model considering area payment*** (LP_T) a maximum of 868,058 thousand Ft gross margin can be realized on 500 ha during 12 years. This means that we can count with an average 144,676 Ft gross margin yearly.

At the same time I analyzed the shadow prices as well. The shadow price analysis made it possible to examine the constraints of the model and the objective function value of the variables.

If the gross margin values of the enterprises shown in Table 5. vary within the given intervals, the production structure is not be changed, because considering the given resources we can reach the highest income still with the received production structure.

Since all the upper flexibility limits of the energy orchards can vary within large intervals (the upper limit is the infinite) without a change would happen in the production structure, therefore, it can be soundly stated that the price change affects the energy orchards less than the conventional arable cultures.

Table 5. The limits of the enterprises' gross margins when the optimal production structure is unchanged with area payment (LP_T)

Plant	Lower bound Ft/ha	Objective function coefficient Ft/ha	Upper bound Ft/ha
Corn	114,267.1	137,806.0	∞
Winter wheat	114,267.1	115,748.0	178,836.8
Turnsole	∞	81,788.6	118,361.5
Colza	- 18,987.1	114,267.1	115,748.0
Locust	- 63,6353.8	- 241,988.5	∞
Poplar	- 446,965.5	- 154,235.9	∞
Swedish willow	- 873,354.4	- 273,428.9	∞

Source: Own calculation

In Figure 5. we can see that the sunflower did not get into the production structure. In order to be competitive with the other enterprises, the gross margin should increase from 81,789 Ft to 118,362 Ft (Table 5.). In this case sunflower would get into the production structure. The roles of energy orchards and corn do not vary (Figure 6.), but the area of wheat decreases.

Figure 6. The built-in of sunflower into the production structure with the involvement of area payment during the examined 12 years

Plant	Lower bound Ft/ha	Objective function coefficient Ft/ha	Upper bound Ft/ha
Corn	114,267.1	137 806.0	∞
Winter wheat	114,267.1	115 750.0	265,466.1
Turnsole	∞	81 788.6	118,367.0
Colza	- 16,957.0	114 267.1	115,750.0
Locust	- 497,753.8	- 96,988.5	∞
Poplar	- 308,365.5	- 54,235.9	∞
Swedish willow	- 734,810.2	- 113,428.9	∞

Source: Own calculation

I got the same production structure with the ***model considering plantation grant (LP_TT)*** as the previous one. The solution showed that on 500 ha for 12 years we can count with a maximum of 894,906 thousand Ft gross margin, i.e. with an average 149,151 Ft/ha/year.

By the analysis of shadow prices I wanted to know how the examined cultures are able to maintain their role in the production structure (Table 6.).

All conventional arable cultures' and energy orchards' objective function coefficient can vary within wide intervals without changing their role in the production structure.
The gross margin flexibility of wheat and colza changed the most compared to the previous model. In case of wheat the interval's lower and in case if colza the interval's upper limit deferred most (Table 6.).

Table 6. Limits of the enterprises' gross margins without changing the optimal production structure with plantation grant (LP_TT)

Plant	Lower bound Ft/ha	Objective function coefficient Ft/ha	Upper bound Ft/ha
Corn	114,267.1	137 806.0	∞
Winter wheat	114,267.1	115 750.0	265,466.1
Turnsole	∞	81 788.6	118,367.0
Colza	- 16,957.0	114 267.1	115,750.0
Locust	- 497,753.8	- 96,988.5	∞
Poplar	- 308,365.5	- 54,235.9	∞
Swedish willow	- 734,810.2	- 113,428.9	∞

Source: Own calculation

The ***model without any subsidy (LP_TN)*** gave the same production structure as the model's with subsidy. The model was run with the gross margin of the non-supported model.

Based on the analysis of shadow prices it can be stated that the flexibility of gross margin is the lowest without subsidy, since the objective function coefficient of crop cultures can vary in the least interval without a change in the production structure. The gross margin value can move in the interval of 6,457 Ft for wheat and of 8,523 for colza (Table 7.).

Table 7. Limits of the enterprises' gross margins without changing the optimal production structure without subsidy (LP_TN)

Plant	Lower bound Ft/ha	Objective function coefficient Ft/ha	Upper bound Ft/ha
Corn	66,667.1	90,206.0	∞
Winter wheat	66,667.1	68,148.0	131,236.8
Turnsole	∞	34,188.6	70,761.5
Colza	- 17,079.1	66,667.1	68,148.0
Locust	- 545,353.8	- 289,588.5	∞
Poplar	- 355,965.5	- 201,835.9	∞
Swedish willow	- 783,715.5	- 321,028.9	∞

Source: Own calculation

Based on the LP models which present systematically the competitiveness of each enterprise we can set that the joint rate of high-income woody energy crops is 46%, and the other part of the land is practical to utilize with conventional arable crops with and without subsidy as well. The harvesting cycle of woody energy crops, which is 2-3 years, has a significant role in it, because especially in the initial period depending on the subsidy we can only realize positive cumulative gross margin balance from year 2-6.

After running these three models it is found that these crop cultures are in the same competitive environment with or without subsidy as well. In the arable crop production woody energy orchards are also competitive compared to the conventional arable crops, which means a new alternative biomass utilization opportunity.

Comparing the results of the calculations presented previously it can be stated that among the three calculation types the energy crops are on the first three places (Table 8.). Colza is on 4th place, 2 cereals on 5-6th places and sunflower is on the last one. The sunflower's last place is due to the fact that it did not get into the production structure either with or without subsidy, and according to the nominal calculations it was on the last place as well.

Table 8. Sequence of the enterprises in different calculations

Plant	Calculation forms the basis of sequence			Average	Order summary	
	Nominal	Dynamic	Crop structure		1st variation	2nd variation
Poplar	3	1	1	1,67	1	1
Swedish willow	1	2	6	3,00	2	2 és 3
Locust	2	3	4	3,00	2	
Colza	5	4	3	4,00	4	5
Corn	4	5	2	3,67	3	4
Winter wheat	6	6	5	5,67	5	6
Turnsole	7	7	7	7,00	6	7

Source: Own calculation

In the last column I summarized the ranks according to the calculation forms, which is the same as the rank of the dynamic calculation.

4. MAIN FINDINGS, NEW SCIENTIFIC RESULTS OF THE DISSERTATION

- I concluded that in the Northern Great Plain region the quantity of wood wastes, cuttings from fruit and vine production and forestry is the highest in Szabolcs-Szatmár-Bereg county. The total quantity in the counties of Hajdú-Bihar and Jász-Nagykun-Szolnok is less than in Szabolcs-Szatmár-Bereg county alone. The total energy use potential is 180,426 tons in the Northern Great Plain region, which means a total 22.62 MW capacity. Based on my calculations in Szabolcs-Szatmár-Bereg county 4, in Hajdú-Bihar county 2 and in Jász-Nagykun-Szolnok county 1 chips-based regional energy-producing power plant could be supplied. The model that I built up is suitable for quantifying, actualizing the results by different cost, price and technological circumstances as well. According to my examinations the ratio of less-favored areas in this region is high compared to the others. From the total less-favored areas of Hungary (878,495 thousand ha) Hajdú-Bihar has 166.4 thousand ha, Szabolcs-Szatmár-Bereg county has 170.04 thousand ha and Jász-Nagykun-Szolnok has 90.0 thousand hectares. From these less-favored lands approximately on 150.0 thousand ha woody energy crops could be produced, which would highly reduce the region's dependence on energy. Thus, under given circumstances for the utilization of less-favored arable lands the production of woody energy crops is a real alternative. The utilization technology is the same as the wastes', so the joint use of waste and energy crops enables a balanced operation.

- Based on the gross margin values the sequence of crops is the following in all cases: willow, locust, corn, poplar, winter colza, winter wheat and sunflower. By dynamic investment indices I analyzed the return of woody energy orchards and I found that the locust, poplar and willow orchards return for the second harvesting cycle with area payments. With the consideration of the maximum 200,000 Ft/ha plantation grant in the first year, all energy crops return after the first harvest.

- I concluded that based on the nominal calculations (average gross margin) and cumulative gross margin values with subsidies the rank of crops is the following: willow, locust, corn, poplar, winter colza, winter wheat and sunflower.

When I took the area payments into account I found that according to the investment economics indices the energy orchards of willow, locust and poplar are favorable. All orchards return for the second harvesting cycle.

Based on the dynamic indices I concluded that the rank of energy crops changed. The poplar came to the first place, then willow and locust.

- For the sound decision-making enterprise analyses are required, however, the resource need of woody energy crops is almost the same as the arable cultures', therefore it is important to analyze the resources systematically. To this end, I created a simultaneous dynamic linear programming model to maximize the gross margin for 12 years. By the application of the multi-periodic model I proved that the execution of systematic analyses is essential besides making enterprise analyses to reveal the real enterprise competition. Based on the results it can be stated that the multi-periodic linear programming model can be applied conveniently to create an optimal "crop structure" with woody energy crops for the simultaneous decision support under optional cost-price-technological circumstances.

5. PRACTICAL USEFULNESS OF THE RESULTS

- I concluded that in the Northern Great Plain region considering the energy utilization of wood wastes, cuttings from fruit and vine production and forestry Szabolcs-Szatmár-Bereg county has the highest potential, which would mean the establishment of four biomass-based (between 2-4 MWh capacity) regional power plant. By the establishment the reduce of local dependence on energy could be promoted, new workplaces could be created and using the waste-heat of the power plants the supply of industrial parks, public bodies, residential buildings, gardens could be solved.
- For the substitute of present produced energy in the Northern Great Plain region the energy extracted from woody energy crops is excellent. In this way the rational use of less-favored areas becomes possible, since an opportunity of using these lands is to produce woody energy crops on these fields.
- The definition of biomass power plant centers and the energy amounts from potential wastes mean an information base for the regional decision-making organizations (local authorities).
- I created such a long-term land-use model, in which the competitiveness of conventional arable crops and energy orchards can be determined on a long term and it supports efficiently the corporate decision-making.
- I found that in short term the conventional arable crops are more competitive, since in the face of high market and production risk they ensure continuous turnover for the farmers. However, in long term the energy orchards are more competitive.
- The crop cultures are in the same competition in supported and non-supported environment. In the field crop production woody energy orchards are also competitive compared to the conventional arable crops, which means a new alternative biomass utilization opportunity.
- It can be soundly stated that the price change affects the energy orchards less than the conventional arable cultures. I explain this with the upper flexibility limits of all energy orchards in the sensitivity analysis.
- By nominal and dynamic enterprise calculations I proved that the profitability and return of woody energy crops are good, which also justifies their wider spread.

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Notes