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Optimization of Biomass Production on Company Level

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Abstract

During our research – the 5.2 subject of BIOENKRF research project – we prepared a programming model in order to optimize biomass production on company level for those agricultural companies which intend to produce bio-energy or use it directly.

During studying the bibliography we found out that many models are known which describes the economic effect of bio-energy plants and the area change that can be agriculturally utilized.

Models can be divided into two groups: econometric models and mathematical programming models. We tried to adapt he known land utilization models in our country but we have not found any results. They demanded too much information as input data which were not registered among the registration data of farmers and there is no regional service which can help the farmers to access the necessary data or the accessment of the needed data would cost a lot of time any money. Most of the studied models are too complicated that they could be applied without separate preparation and costs. Because of these causes a new model became necessary which we named Hungarian Biomassza Modell (HBM).

During the development of the variables of the model our basic principle was to compare plants concerning the use of the end-product (culinary, feeding, energetic, etc.) and production of biomass and bio-fuel.

To outline the casemaps and the target functions, we used data from bibliography, internet and information from company experts.

The first step of optimizing the production layout is the definition of the input system, structuring the input table-system establishing the upload of the model. In case of correct filling out and input into the computer of the input table-system the method works automatically. The solution must be submitted to detailed examination. During evaluation and if there is a demand for new alternatives the inputs can be modified and calculations can be repeated. In the course of this the "competitiveness" of the energetic production can be defined for which experts forecast a great perspective in present times.

After the solving the company biomass production optimization model we made sensibility surveys during which we studied how the change of input-output prices affect the production structure, how the competition position of each bioenergetic end-products depend on the change of resource capacity, how it influences the optimal sowing-structure and the achievable maximum profit. We prepared the 'copyright' version of the model on a CD format – which will be presented at the poster section of the conference.

Keywords: Linear programming, biomass production, optimization

1. Introduction

Nowadays it is becoming more and more obvious that the renewable energy-resources are indispensable. Among renewable energy-resources the energetic use of biomass must be emphasized which allows to use the energy of the Sun in many ways.

Beside the known environmental advantages of using the biomass for energetic purposes – like depressing the emission of carbon-dioxide, sulphur-dioxide and other harmful compounds – social effects are also important which mainly appear in employment-politics, because it solves the problem of employment of a lot of people in the chain of energy-plant production, beginning with research, sublimation through production, extension courses, machine manufacturing and service-networking. Moreover it is also important that it may increase the number of inhabitants of towns that otherwise would be judged for depopulation. It is also not negligible among advantages that it has a significant effect on the safety of energy-supply and payment balance.

It's disadvantages are the high investment, service and operational costs. The relatively big specific volume of biomass (for example: straw) is increasing the costs of transport, storage and the progress of making it storagble (squeezing and baling).

2. The mathematical modeling of energy plant production

Mathematical models are long since used in agriculture for decision making and optimization. Biomass production, just as other plant producing or animal breeding activities, is a complex of very complicated processes with many risks. First of all, it is working with living material which is very sensitive for environmental effects. Second, environmental factors can not be accurately predicted. The quantity of fallen precipitation and its distribution in time along the producing interval can not be calculated and planned. The situation is the same regarding the hours and intensity of sunshine, storm-damages, diseases and harmful agents whose appearance can only be forecasted by presumption variables.

The third doubtfulness is the economic and political environment. The takeover price after harvest and the market price and quantity of competitor producers and plants can also not be anticipated. We can not be sure whether there will be an alternative solution which would be much more competitive than energy-production based on biomass.

Biomass production is a complex procedure and its accurate modeling needs the consideration of varied, more or less aggregated factors. Even the simplest modeling is much more complex than modeling problems of other fields of industry.

In the course of subject nr. 5.2 of BIOENKRF research project we made an LP model for optimizing biomass production on company level, which gives an opportunity for agricultural companies to make simple but simulation operated model calculations.

3. Studying the bibliography

During studying the bibliography we 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.

Models can be divided into two groups: econometric models and mathematical programming models. We tried to adapt he known land utilization models in our country but we have not found any results. They demanded too much information as input data which were not registered among the registration data of farmers and there is no regional service which can help the farmers to access the necessary data or the accessment of the needed data would cost a lot of time any money. Most of the studied models are too complicated that they could be applied without separate preparation and costs. Because of these causes a new model became necessary which we named Hungarian Biomass Model (HBM).

We considered the followings during putting up oue own model:

The "POLYSYS Model": POLYSYS is the American agricultural sector, which involves the national demand, regional supply, animal stock and aggregated profit modules, the simulation model of agricultural politics.
"The Biomass Socio-Economic Multiplier (BIOSEM) Model": This model is suitable for simulating relationships between agricultural products, biomass, energy-production and other sectors of economy.
The "CAPSIM model": it is a partial balance model which serves for the measurement of agricultural development of EU member states. The model considers political changes as well like the change of CAP (Common Agricultural Policy).
The "Life Cycle Analysis (LCA) Model": in this model bio-energy is the subject of examination for the purpose of analyzing the full life cycle of biogases and fossil gases.

The MAP and SASM are made mainly for political decisions but they can be used on other levels also. Decision making can happen on political level, farm level or any other levels. On lower levels solutions can be used as aggregated information about market conditions not directly as control instrument.

SFARMOD Silsoe Farm Model: The point of modeling agricultural land-use is that it considers the ecologic performance (climatic relations, soil facilities, water management, relief and exposure) of each farm in a complex way, it simulates changes and their effect on productivity, then it links them with social-economic features and changes.

4. The main characteristics of the model

HBM is based on linear programming and it allows us to determine the optimal sowing-structure for a chosen agricultural area in case of different target-functions. Optimization for different target-functions was needed because of the economic environment, mainly the change of regulatory system, which makes the biggest profit among given conditions. The main question of the decision with the available area and resource capacity is whether to produce for feeding or rather for energetic purposes. For the sake of generalization we wanted to solve a model which can represent optimization for biogas, bio-ethanol and bio-diesel end-products.

Denomination		unit	Denomination		unit
Wheat (human and animal feed)	x_1	ha	Potato (energetic)	x_{10}	ha
Wheat (energetic)	x_2	ha	Sugar beet(animal feed)	x_{11}	ha
Oat (animal feed)	x_3	ha	Sugar beet (energetic)	x_{12}	ha
Oat (energetic)	x_4	ha	Sunflower (animal feed)	x_{13}	ha
Rye (animal feed)	x_5	ha	Sunflower (energetic)	x_{14}	ha
Rye (energetic)	x_6	ha	Rape	x_{15}	ha
Corn (animal feed)	x_7	ha	Soya	x_{16}	ha
Corn (energetic)	x_8	ha	Sugar sorghum	x_{17}	ha
Potato (traditional)	x_9	ha	Sweet potato (girasole)	x_{18}	ha

Table 1: The variables of the model - to be opened for generalization - eighteen plants coming into question

The requirements for the model explain that only the important coherencies were taken into consideration. The balance conditions were built into the model according to professional and practical needs in periodic divisions.

In the model

- The restrictive conditions can be adjusted to company specialties
- The effects of the macroeconomic regulators to company activities can be handled
- The matrix of the technological coefficients can be changed
- Optimization calculations can be executed along different target-functions

The target-functions:

1. Achievable maximum profit
2. The maximum quantity of produced biomass
3. The maximum quantity of biogas produced from the produced biomass
4. Achievable maximum profit in case of biogas production
5. The maximum quantity of bio-ethanol produced from the produced biomass
6. Achievable maximum profit in case of bio-ethanol production
7. The maximum quantity of bio-diesel produced from the produced biomass
8. Achievable maximum profit in case of bio-diesel production

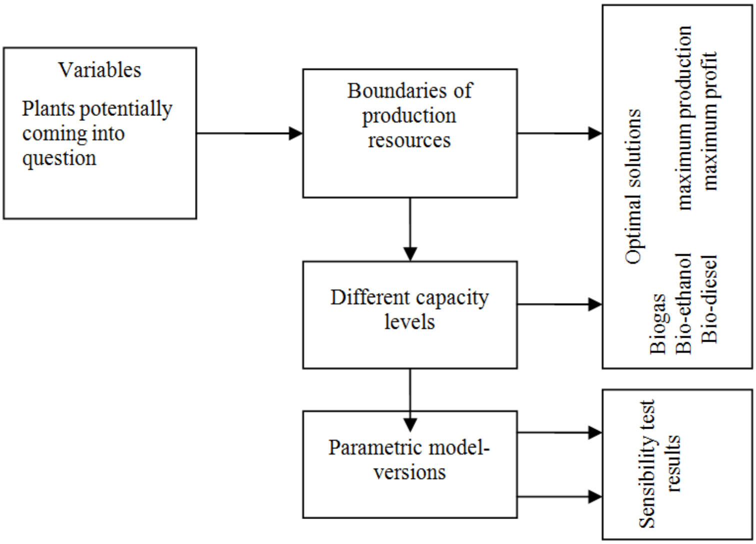

Figure 1: The structural logic of the model

5. The process of optimization of production structure

5.1. Composing the Input table

The first step of optimizing the production structure is the definition of the input-system, composition of the input table-system underlying the fill-up of the model.

First of all, we have to prepare the flowchart of the production of the considerable plants and obtain the necessary data (soil-, precipitation-, heat-, fertilizer-, machine and human labour needs, etc. based on a given production technology).

For the estimation of parameters we studied national and international bibliography. This work-process serves the consideration of professional coherencies and estimation of the important parameters of activities present in the calculation with experts and use of professional data.

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.

When the input table-system is filled in correctly the method works automatically.

5.1.1. Taking resources, capacities into account in agriculture

Available land area: 480 ha
Labourforce per month: 520 hours, in September: 800 hours
Prime mover per month: 820 hours
2nd type machine per month: 900 hours
3rd type machine per month: 400 hours
Total usable fertilizer: 1500 tons

5.1.2. The condition-system of the model

Before determining the condition-system we must mention that in the course of different purpose production the production-technologies are the same, because for example there is no significant difference between the production technology of corn produced for animal feeding and that of bio-fuel, so competitiveness is up to the difference of marketing channels of the end-product.

Seasons are of great importance in agriculture and the needs for production resources shows big fluctuation. That is why the number of balances and so the conditions built into the model is multiplying which can significantly enlarge the model and so there can be more faults.

It is practical to aggregate concerning balance-conditions until the solution is not influenced or we should only take really important coherences into account and build the balance-conditions into the model in periodic divisions.

The balance conditions:

- Non-negativity condition
- The balance condition of area-usage
- Validation of crop-rotation aspects with the unique boundaries of the maximum seeding area of each plant; the area of corns can not exceed the two-third of the total area - the area of sugar beet, rape and sunflower respectively can not exceed 25-25 per cent of the total area.
- Labour force and machine capacity (which were only written concerning the rush-hours because in other periods it is not determining from the aspect of the production structure) - this way the number of balance-conditions can be significantly decreased so the solution is not influenced.
- The quantity of chemical fertilizers

5.1.3. Data used for determination of the target-functions

Data used for determination of the target-functions are concrete data received from experts working in production, they were collected during studying the internet and indices were calculated by us.

At the maximum quantity of producible biogas from biomass we used indices calculated by us from net energy content.

In case of biogas production we calculated with 10 Ft/m3 maximum profit.

In case of bio-diesel production we could not optimize for maximum profit because its producing costs and takeover price are the same: 262.5 Ft/l. Because of the costs of oil extruding the group of considerable plants is becoming smaller.

In case of bio-ethanol production we calculated with a theoretical value (160 Ft/l) concerning maximum profit.

5.2. Execution of model-calculations

This point involves: the formerly determined input data are typed into the computer, the linear programming exercise is filled in and checked, running of the model. After determining the target-function coefficient the solution of the exercise can be calculated by the computer and the optimal production structure can be determined.

5.2.1. Evaluation of calculation results

Summarizing the results and correlating them to the same area the following profit can be forecasted after solving the optimization exercise:

– optimization in case of food production	97 200 000 Ft
– Maximizing bio-gas	14 469 010 Ft
– Optimization in case of bio-ethanol	224 000 000 Ft

The received solution have to be examined in details. Knowing the shadow prices – dual variables – so the evaluation price of exhausted resources the program can be modified. The raised problems and the program can be solved and corrected by enlarging the model, giving more details and coherencies, increasing capacity, putting new activities and introducing new limits.

Considering different alternatives, controlling and judging information concerning the direction of development is a series of consultation of experts in planning and producing. During evaluation and if there is a demand for new alternatives the inputs can be modified and calculations can be repeated. In the course of this the “competitiveness” of the energetic production can be defined for which experts forecast a great perspective in present times.

6. Sensibility tests

The model is perfectly suitable for making sensibility tests regarding the effect of factor-usage change in case of each plants.

Accordingly we studied how the change of input-output prices affect the production structure, how the competition-position of each bio-energy end-product is depending on the capacity change of resources, how the optimal sowing-structure and the available maximum profit are affected if the quantity of land, labour, fertilizer and machine capacity is increasing or decreasing. Due to these changes how the below efficiency and demand indices are shaped in case of biogas, bio-ethanol and bio-diesel production:

Efficiency indices:

- Product per hectare
- Profit per workday
- Profit per one machine-hour

and **demand indices:**

- Area needed for producing one ton of product
- Labour necessary for producing one thousand Ft profit
- Machine necessary for producing one thousand Ft profit

We prepared the 'copyright' version of the model on a CD format – which will be presented at the poster section of the conference.

Control-calculations obviously prove that the Biomass Production Model is suitable for very useful decision-preparation calculations.

With generalizing the model, the users can modify the variables and the condition-system according to their own features so the model can be widely used.

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