Rationalisation of production structure of arable land energy-crops in Hungary

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Rationalisierung der Anbaustruktur von Energie-Pflanzen in Ungarn

1. Introduction

Questions referring to processing, last-use and the economic aspects of different crop-production were in the focus at the first place of past years' researches on energy-crop production. Following the Western-European researches, scientists of Central-East-European countries, which are willing to join forces, also started the domestic adaptation of crop varieties which promise extremely high energetic yields. That is how rape, miscanthus, reed canary grass, and – among the trees – willow and poplar came into the frontline in Hungarian energy-crop researches (GOCKLER, 1999). Though according to my opinion a very important element has been missed out – mainly from the researches on energy-crops (not only in Hungary) – which refers to the construction of energy-crop production system. Here are some questions which have not been clarified yet. Questions like: Where and under what circumstances we should grow our energy-crops? How can you imagine growing energy-crops: mixed with other crops which are for food and forage or separately on energy-crop plantations? Is it necessary to work out a new cultivation method for each

Zusammenfassung

Bei den Energiepflanzen-Anbauprogrammen in Ungarn wurden in vielen Fällen keine fachlichen Untersuchungen durchgeführt. Authentischen Verfahren der Energiepflanzenproduktion und das Ausschöpfen neuer technologischer Potentiale gelingen nur auf Basis exakter Untersuchungen. Der Anbau von unterschiedlichen Energiepflanzen wurde während der Strukturreformen in der ungarischen Landwirtschaft während der letzten Jahre intensiv besprochen, aber den diesbezüglichen agrarpolitischen Vorstellungen fehlte eine fachliche Untermauerung. Die vorliegende Arbeit gibt einen Überblick über Möglichkeiten der Energiepflanzenproduktion unter den ungarischen agroökologischen Gegebenheiten. Während des Projektes wurden 22 Pflanzenarten getestet und in unterschiedliche Energiepflanzenkategorien (Ölpflanze, Alkoholpflanze, Biomasse) eingeteilt. Außerdem wurden Fruchtfolgen für geeignete Energiepflanzenarten gestaltet, sowie Empfehlungen für die Verwendung auf speziellen Standorten beschrieben.

Schlagworte: Energiepflanzen, Fuzzy Logik, Standortoptimierung, Fruchtfolgen.

Summary

Programs on energy crop production, which are quite current in the present days in Hungary, in most cases are lack of profound professional investigations. The authentic way of energy crop production and the real results hidden in the new technologies can only be realised by the results of extensive and far consequent investigations. In the past few years – in connection with the structural transformation of the Hungarian agriculture – such kind of exaggerated ideas had been drafted among the experts of Hungarian agricultural policy which had not been proved professionally. By the data of the present study we would like to give a brief survey of the land potential given by the Hungarian agro-ecologic endowments for plough-land energy crop production. During the programme we had been examining 22 plough-land crops and we had put them into different energy crop cathegories like oil-crops, alcohol-crops, biomass crops. We had created optimal crop-structure for such crops which are the most suitable for energetic production and we had adviced to use them on special habitats.

Keywords: energy crops, Fuzzy Logic, optimising habitats, crop-rotations.

crop? What extend of variety correction should we expect within each differently used-group? May gene manipulation have a chance for life in energy-crop production? Is it necessary to form smaller groups from energy crops when you create a cultivation structure? Or may we talk about energetic crop-rotation?

The only way we can give correct answers to these questions if we number the potential energy-crops and their characteristics in each region, and if we consider on their known and still unknown specialities.

In Hungary, rape production, rape methylesther (RME) production out of rape-seed and its utilisation got into the focus of economic-political interest in the past years. Several studies and analyses studied exploring mainly the technical and economic environment of the topic. Questioning an announcement – given by the government – constituted the background of the present study. According to this announcement in Hungary annually 600–800 thousand hectares of arable land can be used for producing RME. A very opposite opinion, which is widely accepted by the Hungarian farmers, says that the size of the habitat that is appropriate for rape production in Hungary is around 200–250 thousand hectares. If we take into consideration that the re-cropping time of rape is 4 years, which means that the crop may be grown on the same field only after every 4th year; the situation seems more critical. From this aspect, the size of suitable land can be determined by 50–60 thousand hectares in each year.

Comparing the data to the numbers – reported by the government – the potential – implied in rape production – was 10 times overestimated. We carried out an overall agro-ecological research in 1998/99 in order to avoid such mistakes and to clarify which crops have a chance to be grown in Hungary among those which are suitable for being used energetically. In the research, we took one after the other the crops, which can be cultivated in Hungary and we determined which are the ones that can be taken into account in energetic production. During the selection 22 appropriate varieties were found (Table 1). Furthermore, to determine a potential land-size for different energy crops, we used a logical method with artificial intelligence – called Fuzzy Logic – which is quite rarely used in agricultural researches (FOGARASSY, 2000).

Table 1: The list of examined crops
Tabelle 1: Die Liste der untersuchten Pflanzen

Perennial ryegrass	Mays
Barley	Tall fescue
Potato	Sunflower
Wheat	Giant knotweed
Root chicory	Rape
Sweet sorghum	Rye
Sugar beet	Soybean
Topinambur	Sudangrass
Lupines	Triticale
Hemp	Oats
Miscanthus	Reed canarygrass

2. Material and method

Any really consistent method for identifying the proper habitat for certain plow-land crops and also for modelling this process haven't been found yet. The basic problem of this group of questions is that the requirements of each crop can't be described by the tools of classical mathematics. What does it mean in practice?

Each crops' productivity can be evaluated by agro-ecological needs in the terms of land. Optimums of precipitation are usually described by exact values, therefore the precipitation need of a crop is 400–600 mm/year. Mathematically this refers only to the lands with precipitation of 400– 600 mm/year and not more. However this doesn't give us a real answer, because fields with precipitation of 395 or 610 mm/year can be as optimal as fields with precipitation between 400 and 600 mm/year. So we can say that the optimum of precipitation is "around 400-600 mm/year". In order to express „around" we adopted a logical method, which hasn't been used often in agricultural researches before, called "Fuzzy Logic". We adopted the problem – mentioned above – to the basic element of the Fuzzy Logic, which is called the Fuzzy Set, by the following process.

Ecological features – given as optimums, described with discrete values – were marked with Fuzzy "1" **{F=1}** logical value. To express "roughness" we put extreme values by the sets.

The extreme values showed the domains which provide optimal yields in the case of each agro-ecologic feature with at least 80 % probability **{F=0.8}** (Figure 1). We chose optimum and extreme values of the agro-ecological factors for each crop on the basis of the bibliography. We adopted the values of optimums to the logical method in a special form. We took down each ecological characteristic by 2 optimal values (F_{opt1}; F_{opt2}) and 2 extreme values (F_{sz1};F_{sz2}) for each crop. (Table 2) Since the crops' optimal habitat can only be determined by at least the 5 most important agro-ecological factors, apart from temperature requirements we created a Fuzzy optimum Set also for precipitation requirements, optimum of ground water, soil type and pH value (FOGARASSY et al., 1999).

The collective optimum of the agro-ecological optimum sets – based on a logical extreme value of "0,8" – made it possible to give a right designation for the habitats. Comparing the model's habitat-designation to the database of the Ministry of Agriculture , we established a similarity of 94 %, which is quite favourable. (Control method: I compared on 141 checkpoints between modell output and practical datas. In the matter of production datas – throught the country – I compared in case of five traditional arable crops (maize, wheat, sunflower, rape, sugarbeet). On these checkpoints on the average I found differences in six cases. The sample on the average $S_x = 0,99$ with standard mistakes represent the numbers. So this modell, which made by me, locates the optimal production areas with precision level 94 % in every arable crops.)

Databases, having been created for using the habitat-designation model, had been made by digitalising maps from the National Map with the help of a program, called MapInfo. We handled the maps and data parallel with the help of a program-package called ArcView. The basis of our examinations was the determination of agro-ecological optimums for plow-land crops which can be cultivated in Hungary and which are significant also in an energetic point of view. We found it appropriate to choose 5 factors after analysing the physiological characteristics of the crops and also a few different ecological factors which influence the crops' productivity. These are the followings:

- optimal soil-type
- optimal pH value of the soil
- annual precipitation demand
- optimal level of ground water
- optimal annual temperature

We transformed the mathematical optimums into Fuzzy optimums. Then we made up a model with MapInfo and did the field-designation (Table 2).

That is how we got the land potential of the 22 examined plow-land crops concerning the habitats in Hungary. After data-processing, we managed to determine the proper habitats. The land distribution of some significant energy-crops is shown in the following maps (Figure 2, Figure 3, Figure 4).

The size of suitable areas can only give an approximate determination of the production possibilities for each energy-crop. In order to choose the best ones from the crops – with similar land potential – we need further selection. The judgement of plow-land crop production is influenced by the crops' compatibility, their place in an appropriate crop-structure apart from other conditions of crop production (GYURICZA, 2000). In terms of productivity, perennials can be considered more favourably than our root plants or oil plants. The crops, which can be grown on the same field

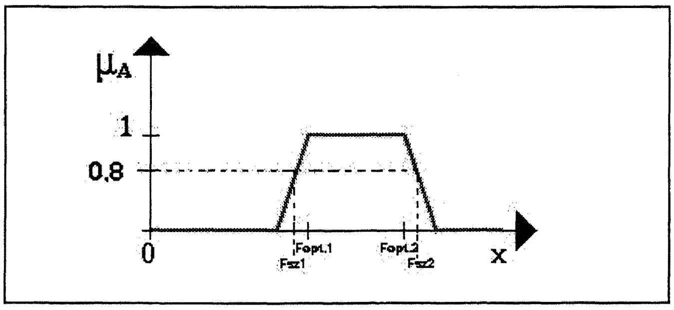

Figure 1: Fuzzy sets by optimum and extreme values
Abbildung 1: Die Fuzzy optimalen und extremen Werte

Table 2: Designation of the sets by practical optimum and extreme values
Tabelle 2: Die Bestimmung der Menge praktischer optimaler und extremer Werte

Sweet Sorgum	Low extreme values F_{sz1}	Optimum$_1$ F_{opt1}	Optimum$_2$ F_{opt2}	Upper extreme values F_{sz2}
Fuzzy SET$_1$ annual temp. demand	7–8° C	8–8,5° C	10–10,5° C	11<
Fuzzy SET$_2$ annual precipitation demand	500–550 mm	550–600 mm	600–650 mm	650–700 mm
Fuzzy SET$_3$ level of ground water opt.	1–2 m	1–2 m	2–3 m	2–3 m
Fuzzy SET$_4$ opt. pH values	4,5–6,8	4,5–6,8	6,8–8,5	8,5–9,0
Fuzzy SET$_5$ soil type (int.)	01, 02, 08, 10,	03, 04, 05, 07, 09, 11, 12,13, 14, 15,	16, 17, 18, 19, 24, 25, 26, 31	23, 27, 28, 29, 30

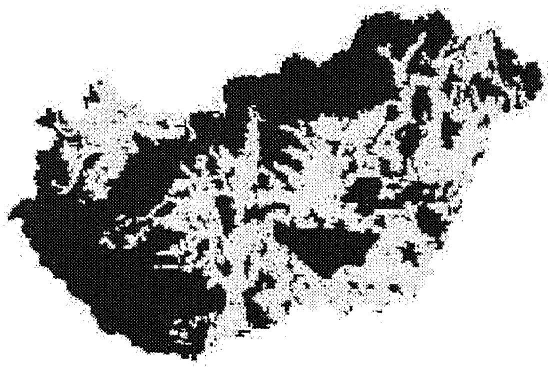

Figure 2: Map of Sweet sorghum area (areas in light colour)
Abbildung 2: Karte der Süß-Sorgum Fläche (hell dargestellt)

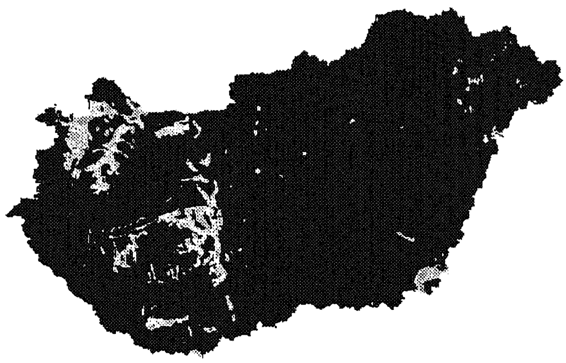

Figure 3: Map of Rape area (areas in light colour)
Abbildung 3: Karte der Rapsfläche (hell dargestellt)

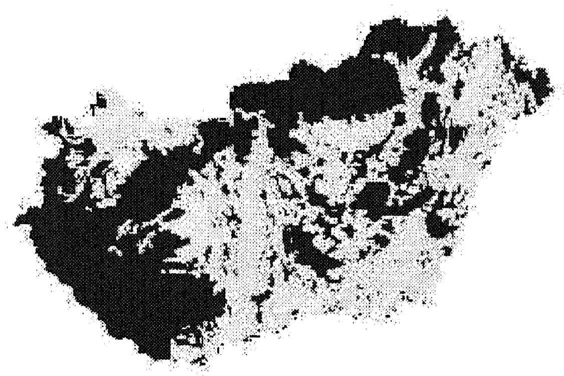

Figure 4: Map of Miscanthus area (areas in light colour)
Abbildung 4: Karte der Miscanthus Fläche (hell dargestellt)

only after 3–6 years, can have unfavourable energetic yields per time units obviously. According to the experiments we found it necessary to put a crop-rotation index (re-cropping time by logical % of the habitat) into the evaluation system. Table 3 categorises our potential crops on the basis of the indexes of each crop.

Table 3: Some different crop-rotation indexes
Tabelle 3: Unterschiedliche Fruchtfolge-Indizes

Crops	Rotation indexes
Potato	0,25
Sugar-beet	0,25
Mays	0,75
Wheat	0,75
Sweet sorghum	0,75
Sunflower	0,2
Rape	0,25
Miscanthus	0,76

In the further evaluations of plow-land crops, we took into consideration the value of energetic yield per hectare and – according to the most recent research aspects – also the annual measurable adsorption of CO_2 (OEGEMA and POSMA, 1994), which is modified with the cost of production. So the final valuation system built up three different components, namely energetic yield, territorial potential (together with the crop rotation factor) and cost of abated CO_2. Based on the different indexes we calculated the order of importance of examined crops (Table 4).

Table 4: Order of importance of examined crops
Tabelle 4: Rangordnung der untersuchten Pflanzen

crops and orders	
I. Alcohol-crops	***II. Solid biomass crops***
1. sweet sorghum	1. miscantus
2. wheat	2. sudangrass
3. mays	3. reed canarygrass
4. sugar-beet	4. hemp
5. topinambur	5. giant knotweed
6. root chicory	6. wheat
III. Oil-crops	***IV. Biogas-crops***
1. sunflower	1. perennial ryegrass
2. lupines	2. tall fescue
3. rape	3. sweet sorgum
4. soybean	4. mays

3. Results

The most important result of the experiment is that those habitats that really provide optimal ecological conditions for certain plow-land production, can be determined properly. Data show clearly which groups of crops could be partners in realisation of energetic crop production (Table 5).

Table 5: Energy crops with their land potentials in Hungary
Tabelle 5: Anbaupotentiale für Energiepflanzen in Ungarn

crop	Fuzzy land potentials (in hectar)
perennial ryegrass	2.430.889
barley	3.812.736
potato	430.062
wheat	3.898.188
root chicory	572.772
sweet sorghum	2.775.083
sugar beet	1.112.430
topinambur	1.199.559
lupinus	1.796.052
hemp	2.873.968
miscantus	3.364.830
mays	2.065.438
tall fescue	1.805.317
sunflower	3.306.068
giant knotweed	3.138.749
rape	239.721
rye	2.588.590
soybean	700.771
sudangrass	3.277.744
triticale	2.588.590
barley	2.573.985
reed canarygrass	1.700.608

The complex system of research made it possible for me to make a relatively impartial order of importance among the crops which can be significant in the energetic point of view. On the basis of analysing the plow-land crops which are productable in Hungary and taking into consideration their land potential of productivity, their energetic yields, their place in a crop-rotation and the annual cost index of avoiding CO_2 we made the following statements. The order of importance of arable land crops – suitable for bio-alcohol production – is: Sweet sorghum, Maize, Wheat, Sugar beet. The same for bio-oil production is: Sunflower, Lupines, Rape. Also for solid fuel production: Miscanthus, Sudangrass, Hemp, Red Canarygrass.

The arrangement by the utilisation can be considered preferable also in terms of energy crop production. According to the well-tried method of industrial crop production, on the same habitat or on the same area the production of those crops (group of crops) is recommended, which have the same technological requirements for processing and final utilisation.

In harmony with that, – in my opinion – a crop-rotation which includes plants for oil, alcohol production, solid biomass plants can be recommended also in energetic crop production. Thus the optimisation of the costly processing of crops – with the same energetic utilisation – could be partly realised. These theoretical examples of how to make up an energetic crop-rotation can be good starting points for making up other versions (Table 6, Table 7, Table 8).

Table 6: A possible crop-structure including alcoholic-crops
Tabelle 6: Eine mögliche Anbaustruktur inkl. Alkoholpflanzen

crops and order	time	utilisation	annual teritorrial ratio
mays	2 years	alcohol	11 %
wheat	2 years	alcohol	33 %
root chicory	1 year	alcohol	11 %
sweet sorghum	2 years	alcohol	33 %
topinambur	2 years	alcohol	11 %

Table 7: A crop-structure including oil-crops
Tabelle 7: Eine Anbaustruktur mit Ölpflanzen

crops and order	time	utilisation	annual teritorrial ratio
sunflower	1 year	oil	25 %
soybean	1 year	oil	25 %
wheat	1 year	alcohol, pyr. oil	25 %
rape	1 year	oil	25 %

Table 8: A crop-structure including solid biomass-crops
Tabelle 8: Eine Anbaustruktur mit soliden Biomassepflanzen

crops and order	time	utilisation	annual teritorrial ratio
hemp	2 years	pellet, bricket	20 %
sudangrass	3 years	pellet, bricket	30 %
hemp	2 years	pellet, bricket	20 %
reed canarygrass	3 years	pellet, bricket	30 %

We created a special system of guidelines as we determined the crop rotation varieties based on the classification by energetic utilisation categories and the hidden land potentials. According to the main phase of this method, we designated optimal areas for producing oil, alcohol, solid biomass, where – out of each utilisation group – at least 4 different energy-crops can be grown. The size of the area for producing oil-plants is: 410.578 hectares (Figure 2). The same area for the alcoholic plants is: 1.024.553 hectares (Figure 3), and for biomass plants is almost up to 2 million (1.990.500) hectares (Figure 4). Analysing the quantities, the greatest opportunity is in solid biomass production in terms of all the habitats in Hungary.

Crops for alcohol cover the half, oil plants do 1/4 of the land potential. If we take into consideration the quality and the utilisation categories of energy sources, we can state that alcohol-crops production can be more preferable in Hungary for energetic use.

This can be explained by the fact that as against the smaller land potential, the energetic value of the produced bioalcohol is double as much as simple fuels'. However, it needs to be mentioned that – with keeping the optimal crop-structure – growing the arable land crops which are in different energetic categories side by side, is inescapable. Therefore, depending on the quality of the habitat, we should gradually reckon on growing them side by side.

4. Conclusion

In my opinion, the most important result of the experiments is the fact that those plant species, which can also be successfully grown for energetic purposes, have been selected from field crops. I have examined the traditional field crops keeping in mind the requirements of energetic production. On the basis of that, I got clear ideas also about what are the technological key-points which induce necessary changes in energetic production. The creation of energetic crop-rotations and special crop-orders that I listed up, may be determinant in the creation of the agricultural-based and energy-generating structure of the following years.

The examination and the necessary change of nutrient content and value of cultivable crops, the necessary adaptation of different stages of production technology to produce and process the final product (a renewable energy source) are only the initial steps. Further tasks include the determination of the soil-cleaning effect and the level of tolerance to pollution of those crops that can be taken into account, moreover include the determination of the opportunities of energy crop production on extreme fields and the discovery of the various opportunities in gene manipulation.

It can be already stated that concerning the specific use of the final product, professional energy crop production is not a mere change in function. If we do not determine the group of cultivated plant species, which can be professionally grown, the technology which should be applied, the nature and volume of application and the profitability, the energetic use of biomass may be an expensive sidetrack of agriculture, which has already high costs.

Agroecological endowments of Hungary are appropriate for crops that are suitable to produce bio-alcohol, contrary to oilcrops that are preferred in Western Europe. Since energy crop production can only be imagined as an individual sector, on the basis of my research I think that the ecological basis, which can be found in Hungary, is good for especially the establishment of agro-alcohol production sector.

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