Possibilities of Biomass Production and Utilization in Hungary

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The continuous development which can be experienced world-wide calls for the increasing utilization of basic materials and energy resources. These usually come from non-renewable natural resources, and although new explorations have led to the discovery of new deposits, in the long run mankind must find substitutes. The wide-ranging utilization of biological resources may be one possible way of doing this. In principle, biological resources are renewable, so they can be considered at least to a certain extent, as inexhaustible.

Another serious world-wide problem is the provision of food for the population. According to statistics, the food annually produced in the world is sufficient to feed the whole of mankind; moreover, the rate of growth in production is not far behind that of the population. Consequently, the problem is of an economic /political/ nature: countries struggling with acute shortages are unable to finance food imports. In addition to the oil and raw material crises of the seventies, in certain regions catastrophic droughts or desertification drastically drew attention to this problem and, as a result, energy has become linked with the issue of the utilization of biological resources.

There are two main problems in treating biomass as a source of energy and raw materials:

a/ New biomass consumers will appear in the market, and this may contribute to a rapid worsening of the food crisis. Alcohol is produced from grain or sugar-cane and fertile soil is withdrawn from food production to grow plants for energy.

b/ Increasing primary biomass production means an increased pressure on the natural environment. It is an open question what the limits of biomass production are, and what should be done to preserve the fertile soil as a renewable resource.

Solutions to the above problems can be suggested only after a comprehensive survey and analysis of the conditions. In Hungary, an investigation of this type was carried out in two phases. Work was begun in 1978, involving several hundreds of researchers working under the direction of the Hungarian Academy of Sciences. First, a survey was made of factors promoting and limiting the development of plant production, i.e. primary biomass production, factors which have a decisive effect on structure and the level of biomass production. This work was conducted within the framework of a project entitled "The Agro-ecological Potential of Hungary in 2000", and was completed in 1980. In the second stage, from 1981 to 1983, the programme was continued under the title "Long-term Prospects for the Utilization of Materials of Biological Origin". The aim was to analyse the biomass production - transformation - utilization system. The question examined here was how production and biomass utilization should be adjusted in view of the known limits to development, in order to achieve given economic targets. In this case, the processes of production and utilization were controlled by the possibilities of utilization and by economic and industrial processing conditions, as well as by natural conditions.

These surveys were not occasioned by a shortage in the domestic food supply, since at present a quarter of the food produced in Hungary is exported, a ratio which is expected to increase in the future. Their purpose was to provide a scientific basis for planning, by determining the possibilities, conditions and limits of development, and also ways in which the latter can be approached or even surpassed. Given these basic research topics, many unanswered questions were raised for scientific research.

As the two projects are closely interrelated, the methodology, results and conclusions will be presented together.

Methodology

The methodology was chosen on the basis of the following main considerations:

- Fertile soil, as one of the basic conditions of biomass production, is a partially renewable natural resource. In many cases its productive potential can still be increased, but renewal is not an automatic process since it is influenced by the technology of production. That is, production and the natural conditions of production interact, even if this interaction is delayed.
- The product structure cannot be determined on an ecological basis, but is a function of economic and social conditions. The product structure must correspond to social needs, i.e. the process of biomass production, transformation and utilization must be examined as a single system. Both transformation and utilization have their effect on the conditions of production.
- The mechanism of the biomass production - transformation - utilization system can only be changed over a longer period, because the mechanism of the effects works slowly. Therefore the only rational way to examine the system is to consider the dynamics and the long-term effects.

The model system for biomass production and utilization is illustrated schematically in Fig. 1.

The mathematical model of the system is a multi-objective control problem. The behaviour of the system is basically determined by plant production, i.e. by the production of primary biomass. In a given time, the level and product structure of plant production were controlled by conditions at the production site, the genetic capabilities of the species produced, the supply of nutrients, and constraints prescribed for the production structure.

Conditions at the production site change in time depending on the agrotechnology used and on amelioration.

The yields are basically determined by the genetic potential, the type and state of the production site, and the climatic conditions at the production site.

The nutrient supply has a direct effect on yields. At the same time, it also affects the state of the production site, since sustained high rates of fertilization, for instance, tend to reduce the fertility of soils.

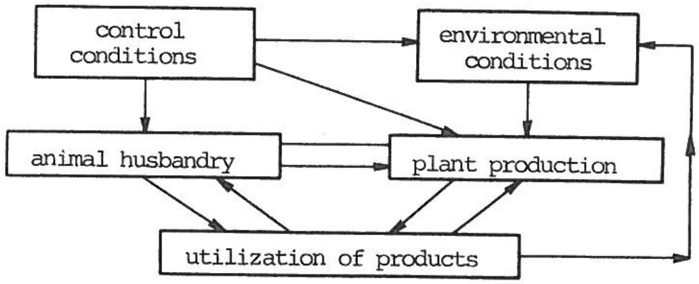

Fig. 1

The schematic model system of biomass production and utilization

The application and utilization of by-products and waste materials may play an important role in the nutrient balance.

The production structure is controlled by a number of factors, such as: the demand for plant products /domestic consumption, exports, seeds, fodder, food processing, etc./, the limits to the sowing structure represented by biological and production site conditions.

The output of plant production consists of two parts: main products and by-products.

Explicit production constraints were considered only for the main products, but the utilization of by-products was also included in the biological cycle.

The fodder needs of animal husbandry and the demands of the food industry affect the structure of plant production in an indirect way.

The animal husbandry sector is determined by: the stock at a given time and the rate of reproduction, the choice and quantity of fodder available, the animal housing facilities available, and the demand for products of animal origin.

An examination of the dynamics of changes in the animal stock is central in the case of cattle and sheep, since the rate of development of these species is limited by their low reproduction factors. In the case of monogastrics /pig, poultry/, the speed of changes in the stock has practically no biological limits. In addition to the rate of reproduction and the exsection, changes in the stock are affected by the breeding conditions and deaths. In feeding studies, the physiologically necessary amount of fodder was determined for each species, and both the composition of the stock /e.g. cows, beef cattle/ and the breeding technology were also taken into account. Feed rations were expressed in terms of digestible protein, starch value, fibre content, protein concentration and lysine. The supply of feed for animal husbandry is provided by plant production and fodder imports, fodder originating from the processing of by-products and the wastes of animal husbandry is limited, and is also determined by the quantity and choice of available fodder. Animal housing can be modified by investments. The constraints on animal products are determined by the expected domestic consumption and exports. As in the case of plant production, the formation of by-products and wastes /manure, dead animals/ and the possibilities of utilizing them are also considered.

When examining the utilization of products, the following question was raised: Given the cycle of biomass production - transformation - utilization, where is it possible to intervene in order to increase and rationalize utilization? Reserves can be expected primarily in the utilization of by-products and wastes.

By using by-products and wastes as fodder more protein becomes available and, as less land is required for fodder production, plant production for other purposes can be increased.

The utilization of phyto-materials, manure, liquid manure and sewage sludge in fertilization serves a twofold purpose: fewer mineral fertilizers will be needed, and the organic matter content /and thus the fertility/ of the soil will be increased.

The waste material formed during primary, secondary and tertiary biomass production contains a huge quantity of energy, part of which can easily be utilized by combustion, pyrolysis or biogas generation. Apart from the actual economic gains achieved by utilizing by-products and wastes, it must also be remembered that the accumulation of these materials has an extremely harmful effect on the environment, thus their utilization is an act of environmental protection.

Dynamic changes in the conditions at the production site may be of two kinds:

- inappropriate technology or failure to maintain the required nutrient level will decrease fertility /compaction, acidification, erosion, etc./;
- proper technology, fertilization, and - if needed - amelioration will result in higher fertility.

Amelioration and the level of technology applied are regulated by control conditions. The behaviour of the system is basically controlled by the constraints laid down for the structure and the quantity of production, i.e. the development alternatives, and by the investment limits. The control variables of the system represent investments.

In an analytical form, the system is described as a control problem. The equation expressing the dependence of the quality and quantity of arable land on agricultural activity is given as:

$$\underline{x}/t+1/ = \underline{x}/t/ + E\underline{z}/t/ + C\underline{u}/t/ - \underline{d}/t/$$

$$\underline{x}/t_o/ = \underline{x}_o$$

where:

$\underline{x}/t/$ = the amount of arable land in period t in terms of quality grades;
$\underline{z}/t/$ = sowing structure and technological level, representing production activity;
$\underline{u}/t/$ = investments in land reclamation and other projects enhancing productivity;
$\underline{d}/t/$ = decrease in the land available for agricultural production due to external factors, and
$\underline{x}_o$ = initial state of the system.

A change in productivity, i.e. the transfer of land from one quality grade to another is represented by the matrix E when it is a consequence of production activity and by the matrix C when it is a consequence of investments.

Controlling conditions are given in the form of

$$B\,u/t/ \leq \underline{u}_N/t/$$

$$\underline{u}/t/ \geq \underline{0}$$

where:

$\underline{u}_N/t/$ = capital available for investments, and

$\underline{B}$ = matrix representing allocation constraints.

The functioning of the system within a single time period is described by the formulae

$$\underline{x}\ /t/ = F\ \underline{z}\ /t/$$

$$A\ \underline{z}\ /t/ \leq \underline{f}\ /t/$$

$$H\ /\underline{z},\underline{y}/\ /t/ \leq \underline{0}\ .$$

The sowing structure is represented by the matrix F, specific nutrient requirements by A and the amount of nutrients available in the period t by the vector $\underline{f}/t/$. The function H $/\underline{z},\underline{y}/$ describes the relationship between sowing structure and the national product structure, the latter being represented by the vector $\underline{y}/t/$.

The transfer from inputs to outputs via the vector $\underline{z}/t/$ of the sowing structure is given as

$$\underline{y}\ /t/ = G/t/\ \underline{z}/t/$$

$$\underline{y}_o\ /t/ \leq \underline{y}/t/ \leq \underline{y}_1/t/$$

with G/t/ constituting hectare yields, and $\underline{y}_o/t/$ and $\underline{y}_1/t/$ representing the lower and upper values for the production of individual crops.

Results and conclusions

Since 1980 was chosen as the starting year of the survey, the aggregated production data for that year will be presented first /Table 1/:

1. More than half of the biomass produced /primary and secondary/ consisted of by-products, and 70-75% of this huge quantity was not utilized.

2. Almost two-thirds of the primary biomass treated as main product was used as fodder, i.e., in Hungary the most significant biomass consumer and transformer is the animal stock.

3. As a biomass transformer the animal stock works at very low efficiency, the output /meat, milk manure, etc./ is only 43% of the input expressed in dry matter; in fact, if only the main product part of the output is considered, this figure is not more than 8.5%.

It is worth mentioning in connection with animal husbandry that, when comparing fodder input and product output, almost 60% of the dry matter "disappears". The primary carbon content of this quantity of organic matter amounts to 30 million tons, approximately corresponding to the C content in the CO_2 expiration of the animals. This was proved by theoretical calculations.

4. In Hungary the annual production of forest biomass is substantially less than the biomass of plant production /it is on a level similar to animal husbandry, but the main product/by-product ratio is reversed/.
The total organic matter content of forest biomass expressed in dry matter amounts to 162 million tons, which is three times as much as the total biomass annually produced.

Let us now compare these actual data with a production version projected for the year 2000 /Table 2/. The detailed production structure will not be described here, but it is worth mentioning that, in both 1980 and 2000, cereals represent 60% of the primary biomass main products. This proportion is even higher in the case of by-products.

Table 1

Biomass production and utilization in 1980 /dry matter in thousand tons/

Product dry matter		Seed	Food	Fodder	Industry	Exports	Energy	Soil nutrient + litter	Change in stocks	Not utilized
				A. Plant production /product + import/						
Main product	23 009	517	3 166	14 918	302	1 553	-	-	1 447	1 106
By-product[x]	20 594	-	-	1 245	92	-	1 184	1 677	949	15 447
Total	43 603	517	3 166	16 163	394	1 553	1 184	1 677	2 396	16 553
%	100	1.2	7.2	37.1	0.9	3.6	2.7	3.8	5.5	38
				B. Animal husbandry						
Input 16 401										
Main product /milk, meat, wool, etc./	1 421	-	826	49	62	445	-	-	-	39
By-product /dead animals, manure/	5 678	-	-	30	-	-	-	1 000	-	4 648
Total	7 099	-	826	79	62	445	-	1 000	-	4 687
%	100	-	11.6	1.1	0.9	6.3	-	14.1	-	66.1

Forest biomass:		
	wood felled	4 143
	logs, foliage, shrubs	1 145
	increase in wood stock	1 708
	Total:	6 996

[x] excluding stalk and root remnants

For the version prepared for 2000, the following was assumed:

a/ Crop yields will increase along a logistic curve until 2000 depending on the species. The rate of growth in the total production is determined by cereals. It is assumed that only a slight /30%/ increase can be expected from the present species.

b/ The area of fertile soil will decrease by 150 thousand hectares. In order to reach the planned level of production, more than 500 thousand hectares must be ameliorated and an average 2300 thousand hectares should be cultivated using an ameliorative technology in order to prevent a decrease in soil fertility.

c/ There will be no structural change in the animal stock. An overall increase of 25% was assumed, as was a higher proportion of by-products and waste materials in feeding.

The utilization of by-products in large quantities must therefore be preceded by a considerable reshaping of the structure of animal stock.

In 1980 the animal stock consisted of 1,918 thousand cattle, 8,330 thousand pigs, 120 thousand horses, 3,090 thousand sheep and 42,714 thousand poultry.

The high proportion of pigs and poultry is primarily due to the fact that the country has good conditions for the production of fodder for these species. One important economic factor is the low rate of capital investment required when breeding these species. In addition, due to their fast reproduction, they return investments within a shorter time and production can be more easily adapted to market changes. Mention must also be made of the effect of the traditional Hungarian diet structure, leading to a high, 80% share of pork and poultry in domestic meat consumption. Hungarian traditions and circumstances are favourable for the development of pig and poultry production, but this results in a sustained protein-fodder deficit.

It is clear from Table 2 that the utilization of the main products of biomass production is ensured for a long time to come, since it can be assumed that there will be sufficient demand for cereals and meat on the world market. Problems appear with regard to the utilization of biomass produced as by-products and waste. It may be seen in Table 1 that a considerable proportion of the biomass produced in 1980 was not utilized. Limits to utilization will continue to exist in the future, but as a result of the expected development in biotechnology and the restructuring of the value system, these limits will be gradually relaxed, and development aimed at the more and more complex utilization of the biomass will be maintained.

According to the results of the survey, there are three areas where significant development can be expected. These are as follows: feeding, energy production and the nutrient supply of the soil.

The main products of plant origin can be expected to form the chief sources of fodder. More than 60% of the main products of plant production are currently utilized as fodder, but this cannot be said for the by-products, which amount to almost half of the total organic matter.

The plant production version assumed for 2000 contains 3 492 thousand tons of starch equivalent and 193 thousand tons digestible crude protein as harvestable by-products. Theoretically, this quantity is equal to the fodder needs of 188 thousand tons of beef cattle on the basis of protein content.

If the nutrient content of 1.5 million tons of straw, 3.0 million tons of maize stalks and 320 thousand tons of sugarbeet tops is considered

Table 2

Biomass production and utilization projected for the year 2000 /dry matter, thousand tons/

Product dry matter		Seed	Food + food industry	Fodder	Industry	Export reserves	Energy	Soil nutrient + litter	Loss
A. Plant production									
Main product	29 700	600	3 800	17 500	300	7 500	-	-	-
By-product	27 000	-	-	5 200	1 200	-	3 500	12 500 + 3 000	1 600
Total	56 700	600	3 800	22 700	1 500	7 500	3 500	15 500	1 600
%	100	1.0	6.7	40.0	2.7	13.2	6.2	27.3	2.9
B. Animal husbandry									
Input 23 200									
Main product /meat/	1 721	-	944	60	75	595	-	-	47
By-product	8 524	-	-	19	-	-	850	6 550	1 105
Total	10 245	-	944	79	75	595	850	6 550	1 152
%	100	-	9.2	0.8	0.7	5.8	8.3	63.9	11.3

as the amount of realistically utilizable by-products, then their total nutrient content is 512 thousand tons of starch equivalent and 36 thousand tons digestible crude protein, which would cover the fodder needs of 45 thousand tons of beef cattle.

The secondary biomass, or organic matter of animal origin, also includes products, such as dead animals, manure, hatchery wastes and the like, which could be used for feeding, but at present their utilization is far from being general practice. An annual 50 thousand tons of dead animals can be expected, which, after processing, could provide a considerable amount of protein fodder.

Tertiary biomass produced by the food industry also contains a considerable amount of by-products and wastes, a significant proportion of which could be used as fodder.

According to the survey, the starch equivalent and protein content of by-products which could be used for feeding purposes in 2000 are likely to be those presented in Table 3.

Table 3

The starch equivalent and protein content of by-products planned for feeding purposes in 2000

By-products	Starch equivalent	Protein
	thousand tons	
field crops	512	37
of animal origin	145	75
of food industry	419	92
Total:	1 094	204

This quantity represents 6% of the total starch equivalent and 8% of the protein content of the fodder available from plant production.

As a source of energy, biomass once played an important role in energy consumption. The small-scale farms of the past strived to achieve a full-scale utilization of the biomass; the peasants collected and utilized wastes and by-products of both plant and animal origin, mainly as combustibles, fodder or construction material. Also, a more significant proportion of the wood felled served for combustion purposes than today.

The appearance of modern, intensive agricultural technologies did not promote the energetic utilization of the biomass and, as a result, only 2% of the national energy balance stems from the biomass /fire-wood/. It was mainly the rapid rise in the price of fuel oil which drew attention to this source of energy. The forecast energy content of the primary biomass in 2000 is illustrated by the following figures:

plant production:	main product	499.4 PJ
	by-product	469.1 PJ
forestry:	main product	87.2 PJ
	by-product	16.8 PJ
	Total:	1 072.5 PJ

which is equivalent to the caloric value of 25.6 million tons of oil. The energy content of the primary biomass amounts to more than two-thirds of the present energy consumption of the country. Of course, this is only a theoretical comparison, since it is impossible to burn everything, especially the main products of plant production. Even the full-scale combustion of straw and maize stalks is not envisaged. The combustion of straw and other by-products with a low moisture content can be considered feasible. The combustion technology for maize or sunflower stalks, however, needs further development. A precondition for the energetic utilization of the biomass is the development of large-scale methods of collection, storage, and, where necessary, preliminary processing as well.

For the future, the production of briquets would appear to be a suitable form in which biomass could be collected and stored economically, since it would enable products to be transported over longer distances and to substitute coal and oil combustion to a large extent. Briquetting will put an end to the seasonal character of by-product combustion. The idea of combusting 3.2 million tons of by-products appears to be a realistic aim for the year 2000. This amount is equivalent to the energy value of 640 thousand tons of fuel oil.

Another possibility for energetic utilization is biogas generation. In this field, not only the wastes of plant production, but also those of animal husbandry and the food industry could be utilized, as well as sewage sludge. A certain advance can be expected in this field, but it must not be forgotten that cold winter conditions are not favourable for biogas generation. The significance of biogas generation lies not only in the energy produced. It is important to emphasize that the organic matter residues formed during the process constitute fertilizer of good quality. Moreover, it is a way of processing pollutants, e.g. liquid manure and sewage sludge. Consequently, a more extensive use of biogas generator would contribute to the protection of the environment.

In plant production, an important factor in increasing yields is to maintain soil fertility and to provide nutrients for the plants. An important role is played here by the regular return of organic material to the soil.

The NPK content of field crops is illustrated in Table 4.

In the biomass produced by animal husbandry, an important role is played by manure, at least as far as quantity is concerned, since it represents more than 80% of the total dry matter.

The amount of stable manure expected to be produced in 2000 is 20 million tons, while that of liquid manure is 50 million m^3. The nutrient content of stable manure is expected to be 120 thousand tons of N, 60 thousand tons of P_2O_5 and 140 thousand tons of K_2O. The figures for liquid manure are as follows: 50 thousand tons of N, 10 thousand tons of P_2O_5 and 30 thousand tons of K_2O.

Table 4

The NPK content of field crops in 1980 and 2000 /in thousand tons/

Field crop	1980			2000		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
main product	669	286	563	930	370	800
by-product	165	92	300	230	130	420

So far, only preliminary results are available on the utilization of sewage produced by communities and by industries processing materials of biological origin, and of sewage sludge. Profitability indices fail to encourage sludge utilization, although it would be justified by environmental considerations. According to the forecasts, the amount of sewage from settlements with drainage systems will reach 644 million m^3 in 2000. The organic matter content of this quantity will amount to 650 thousand tons, with an NPK nutrient content of 65 thousand tons. After sewage treatment, the sewage sludge will contain approximately 116 thousand tons of dry matter, with an organic matter content of 58 thousand tons and an NPK content of 5.8 thousand tons.

Compost production and biogas generation also belong to the field of sewage slude utilization. At present, the by-products ploughed under /mainly cereal straw and maize stalks/ and the organic manure distributed amount to only a small proportion of the nutrients utilized. This ratio could be increased by accelerating the decomposition of cellulose in the soil by biotechnological methods. The solution of this problem appears to be feasible within a short time. The ploughing under of straw and maize stalks and the extensive application of organic manure not only provide a considerable amount of nutrients for the soil, but, given the present reliance on chemical fertilizers, they constitute an indispensable condition for the maintenance of adequate soil quality for an improvement in the effectiveness of fertilizers and for a reduction in the need to artificially replace microelements. Of course, the nutrient content of the organic matter ploughed under is not fully utilized, but this nutrient source is a good supplement to fertilization and could reduce the rate of increase in the use of mineral fertilizers.

Summary

It was not possible to give a review of all the results of the survey or to describe the methodology in detail in this short paper.

Among the most important conclusions, a description is given of possible ways of utilizing by-products. Development in this direction, however, will not come automatically. The types of by-product utilization suggested in this paper offer real possibilities, but if they are to be achieved, a change in attitude must first occur. The aim must be a full-scale evaluation and utilization of the biomass.

Besides the development of appropriate technologies, the key issue is the elaboration of an adequate incentive and management system.

As a final conclusion, it can be said that the world-wide over-optimism in the field of the energetic utilization of the biomass does not appear to be justified in the case of Hungary. There are possibilities for development, but in the authors' opinion, food production is the primary goal of biomass production and will continue to be so in the future. As long as there are millions of people starving in the world, food production cannot be reduced in the interests of alternative goals.

The task for the future is to protect renewable natural resources so that they can provide larger amounts of food. As a supplement to this activity, efforts must be made to provide possibilities for a full-scale, rational utilization of the biomass.