ORIGINAL ARTICLE

ENERGETICALLY CLOSED AGRICULTURAL SYSTEMS
ENERGETICKY UZAVŘENÉ ZEMĚDĚLSKÉ SOUSTAVY

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ABSTRAKT

V předložené práci byl učiněn pokus o kvantitativní vyhodnocení uzavřené zemědělské soustavy s cílem, aby se stala stabilní a invariantní. Uzavření v 1. stupni je řešeno využitím části odpadových hmot v podhorském a horském hospodářství pro výrobu bioplynu. Druhý stupeň předpokládá zařazení ploch energetických plodin – řepky olejky – do vnitřní struktury soustavy a posléze 3. stupeň uzavření soustavy uvažuje využití bioplynu pro transformaci části škrobnaté produkce – obilí na etanol jako pohonnou hmotu. Princip uzavřenosti soustavy vyžaduje optimalizaci její vnitřní struktury na principu rovnovážného stavu uhlíkové bilance.

KLÍČOVÁ SLOVA: zemědělská soustava; energetika; uzavřená zemědělská soustava; horská a podhorská oblast

ABSTRACT

In the presented work, we attempted to carry out a quantitative evaluation of a closed agricultural system, with the aim of increasing its stability and invariance. Closing the agricultural system in the first degree means using a part of waste materials in a submontane and mountain farm for the production of biogas. The second degree presupposes the inclusion of crops rich in energy– oil-seed rape - into the inner structure of the system, and finally the third degree of closing the system considers using biogas for transformation of a part of starch production – cereals – into ethanol as a fuel. The principle of closing the system requires the optimization of its inner structure relying on the principle of well-balanced state of the carbon processes.

KEY WORDS: agricultural system; energetics; closed agricultural system; mountain and submontane regions

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DETAILED ABSTRACT

The necessity to bring agricultural production into harmony with the economics and ecology of the land area led to the solution of the structure of an agricultural system as an energetically closed system. The principle consists in limiting the input of external energy and substituting for it the energy produced in the same system. If the system shall answer this purpose, it has to be based on a well-balanced state of the carbon-related processes. Only this way can an agricultural system become a factor establishing progressive development for a land area, in which it is acting, and at the same time, facilitate the usage of all vegetation factors for the accumulation of organic matter – yield. That is why the structure of the system must be optimized on the carbon balance principle.

The solution for the ecological and the economic principle then consists in three grades, which close the system:

- the 1-st grade represents the transformation of waste organic matter to biogas.
- the 2-nd grade includes energy-rich crops, which can be used for fuel production.
- the 3-rd grade requires stationary use of biogas for driving distilleries, where a part of starchy crops is transformed to ethanol as energetic mass for driving agricultural machinery.

In combining the mentioned three grades, the own energetic base of the agricultural system is being formed, and it closes the system. Such structure of an agricultural system has been suggested on the basis of system analysis of submontane- and mountain regions, and necessary parameters have been computed. This way, it has been possible to quantify the grade of closing the system. High cattle stocking density, particularly in mountain and submontane regions, has been proved to be a precondition of this solution. The volume of gained energy depends also on the cattle stock per hectare of agricultural land.

The total energetic balance of the analyzed area of 7 441 ha agricultural land (5 758 ha arable land) was, in these three grades of closed system transformation, equal to 2 239 426 kWh for transport and agricultural technologies. Using it for driving an electric generator with 400 kW power output, the gained energy would be sufficient for two such generators.

This solution of a closed agricultural system enables us to utilise a part of the acreage for its own needs, and to limit the input of external energy. All presented examples suggest possibilities, which could solve strained economic problems in agriculture, particularly in mountain and submontane regions, by decreasing the costs of external energy entering the system, by more perfect utilization of waste materials and the own production of the system. That is why no decrease of production is necessary to come about, but the intensification with the effect described above, could be profitable.

INTRODUCTION

The problem of renewable sources of energy has been studied from many aspects – wind energy, transformation of energy of sun radiation, water energy, and use of biomass to energetic purposes ([1]). In our case, we have concentrated on possibilities to utilise the energy of waste matters in agricultural systems.

Agriculture, as one of the oldest branches of human activity, has undergone, from the time of neolite, a process of complicated development, which was defined by demands of the population density, but above all by conservative and progressive conditions of the land area, in which it has been developing. Sizeable drives of scientific knowledge and technology gradually changed classical agricultural technologies into technologies of the industrial type. At the same time, a new phenomenon came into being – agriculture becomes a key factor in forming the landscape and ecology under very demanding economic conditions.

Use of sun radiation is, and will always be, the main and unchangeable principle of agriculture, regardless of means and technologies used for achieving this aim. At that, it is not only a matter of sun energy accumulation and its following dispersion but also, how to be a good manager of accumulated energy, how to transform it into other energy forms and use it in that different form. This process is possible, so we can close the agricultural system on the energetic principle. In the work presented, we attemped such an energetic closing of an agricultural system.

Generally, we define an agricultural system as an open system, which is dependent on all the conditions, under which it is developing. In order to stabilize the agricultural system, we must put in a considerable quantity of energy and work, when the energy of sun radiation, genetical potential of crops and animals should be used for the necessary accumulation of organic matter and its quality ([3], [4]).

This fact led us to the thought, to try to turn this trend in such a sense, that the input of external energy, that comes from sources outside the system, will be limited, and energy produced by the system itself will be used. We supposed, that with the grade of limitation of external energy input, the system will be closed energetically, and will become invariant in a considerable measure. The level of energetic invariance then involves a substantial increase of favourable economic parameters. In addition to this, the world trend of the availability of cheep energy is developing very unfavourably, so it can be expected, as numerous analyses of European countries show, that this fact will be experienced in the production of food and raw materials produced by agriculture.

To produce energy and use it in the agricultural system itself, the system must be equipped with appurtenant machine and building technologies. Also the inner structure of the agricultural system must correspond to this requirement. That means, when crops rich in energy are used, the C-balance, the balance between carbon sources and consumers, must be taken into account ([6]). The quantity of carbon available in the structure of the agricultural system must also compensate for the transformation of a part of waste materials used for energy production in the system before their returning into the soil. This produced energy is supposed to be used in the agricultural system itself and compensate for a considerable part of external energy (fuel, electricity, gas). So, a closed circuit – compensation feedback – comes to being in an agricultural system. This compensation feedback is a cyclic one, substantially closes the system in the energetic respect, and increases the grade of its invariance. For the feedback to be functional, a special aggegate „Renewing of energy sources“ must be included in the system. Its content is represented by the following:

1. technologies, which allow the utilization of a part of waste materials in the agricultural system and the transformation of it into utilizable energy,
2. change of the inner structure of the agricultural system by including energetic crops, from which energy can be released and rationally used in the system,
3. equipment for the transformation of a part of the production (grain, potatoes and others) to energetically rich substances used as fuels,
4. technologies, which allow the return of biogenous elements into the system and eliminate losses.

MATERIAL AND METHODS

In the presented work, we followed the first three aspects listed above in a mountaine and submontane region. Mainly, the objectives of the work are to solve the following problems:

1. Quantitative evaluation of the energy cycles in an agricultural system at the transformation of waste materials into biogas (content 70 % CH_4)
2. Inclusion of rape *(Brassica napus var. arvensis)* into the inner structure of the system and its evaluation from the viewpoint of energy.
3. Earmarking of a part of cereal production in the inner structure of the agricultural system as crops which can be transformed into alcohol (ethanol) for using it as a fuel.

For the solution of the task, we have chosen a microregion, conforming to the area of former Dolní Dvořiště state farm, in Český Krumlov district ([8, 9]).

Acreage of the microregion is 7441 ha agricultural land, from which 5758 ha is arable land. The total cattle stock is 5319 cattle units. A ten-year period (1976 – 1985) is assessed. Elevation above sea level of the areas is max. 733 m, approximate 644 m and min. 537 m. The territory has been chosen as a microregion with the aim of showing the possibilities for all subjects farming here or will do so in the future. The work presented can also help the objective evaluation of appropriations into agriculture and formulate demands on directing agricultural research.

Symbols and indications used in the work

Symbol	Meaning
P	acreage of land [ha]
$\mathbf{P_{or}}$	acreage of arable land [ha]
$\mathbf{P_z}$	acreage of agricultural land [ha]
$\mathbf{P_i}$	acreage of crops [ha] (Individual crops are marked by indexes)
S	general symbol of crops (Individual crops are marked by indexes)
$\mathbf{Y_s}$	dry matter in crop yield [$t.ha^{-1}$]
$\mathbf{\Sigma Y_s}$	dry matter in total yield of a crop [t]
ΣC	active carbon [t]
C-balance	carbon balance in t
DJ	cattle unit
ΣZ	cattle stock (in cattle units)
ΣZ (f)	actual cattle stock (in cattle units)
$\mathbf{h_z}$	cattle stock per hectare of agricultural land
$\mathbf{k_n}$	feed ration for cattle

Crop indices	
0	**annual fodder crops** (silage crops)
1	**perennial fodder crops**
ri	roots of perennial fodder crops
2	**cereals**
2z	grain
2sl	straw
3	**root and tuber crops**
4	**grassland**
5	**oil bearing crops (rape)**
n	**other crops**

Parameters used for the analysis of energy processes and for the optimization of the inner structure of the agricultural system ([6]):

$C_1 = 3,74$ characteristic of the 1st radiant Planck's constant
$C_2 = 1,4388$ characteristic of the 2nd radiant Planck's constant
$C_3 = 0,3847$ ratio C_2 / C_1 – parameter for conversion of dry matter to active carbon. ($C_2 / C_3 = C_1 = 3,74$).
k_n = feed ration of dry matter for a cattle unit DJ (Z) 2,599 v $t.year^{-1}$ (note: $C_1 / C_2 = 1 / C_3 = 2,599$)
$k_n = 2,599\ S_1+S_4 + 0,701\ S_0 = 3,3$ = theoretic feed ration for cattle
$kC_{ri} = 0,36$ (0,3 - 0,6 - 0,9) for conversion of $Y_{s\,ri}$ to C_{ri} for the 1st, 2nd and 3rd year of stand use
$k_z = 0,065$ conversion of grain or seeds to active carbon in a system
k_v = utilisation coefficient 0,785
Eta 0 = $\Sigma Y_{s0} / \Sigma Y_{s(1+4)}$
Omega 1 (ω_1) = $\Sigma C_{(0,1,ri,4)} / \Sigma C_{2\,z+sl}$
Omega 2 (ω_2) = $\Sigma C_{(0,1,ri,4,2\,sl)} / \Sigma Y_{2\,z}$
$k_s = 1,2713$ = coefficient for conversion of grain to the optimal volume of cereal straw

Energetic parameters ([6]):
1 DJ = Z = 0,943 m^3 biogas daily = 1,69 kWh energy
1 liter oil = 1,5 m^3 biogas (70 % CH_4) = 1 kg black coal
1 kg black coal of 32 MJ fuel efficiency = 1,5 m^3 biogas
1 m^3 biogas = 1,6 ÷ 1,9 kWh (counted 1,69 kWh)
1 kg oil = 1 kg black coal = 2,52 kWh = 1,5 m^3 biogas
1 m^3 biogas is equivalent by heating power to 0,5 kg petrol or heating oil (40 ÷ 50 MJ)
1 kg ethanol = 1,13 liter
1 kg ethanol = 3,38 kWh

RESULTS

Analysis of the original structure of agricultural system of the microregion is presented in Table 1.

Evaluation:

Parameters of the original structure are considerably out of balance. At **Eta 0**, the difference from the standards is + 0.136, that is, 49.6 %, which is inacceptable for mountain conditions, with regard to low alkalinity of grass stands.

Omega 1 exceeds norm by 55 %, and **Omega 2** by 34 %. There is a considerable surplas of carbon sources in relation to cereals, and it can be useful to think about their other, for examle energetic, use.

ΣZ (cattle stock) is lower than it could be according to the counted standard. The reason is the quality of the feed ration, as the real $\mathbf{k_n}$ is 4.35 $t.Z^{-1}$ against the optimum of 3.81 $t.Z^{-1}$.

For the entioned reasons, we optimized the original structure using the algorithm of the carbon balance principle for calculation of an optimal structure.

Table 1: Analysis of the original structure of the agricultural system of the microregion

Crop	P ha	P % P_{or}	P % P_z	Y_s $t.ha^{-1}$	ΣY_s t	ΣC_k t
S_0 – annual fodder crops	1127	19.57	15.15	5.98	6739	2035
S_1 – perennial fodder crops	1465.7	25.46	19.70	6.73	9864	2979
S_{ri} – rhizomes					9864	2130
S_{2z} – cereals – grain	3111	54.03	41.81	3.43	10670	694
S_{2sl} – cereals - straw					13551	5213
S_3 – root and tuber crops	54.3	0.94	0.73		21171	6421
S_4 – grassland	1683		22.62	3.9	6564	1982
Total (P_{or})	5758	100.0			50970	13136
Total (P_z)	7441		100.0		57534	15118

Parameters:

Parameter		Parameter	
Eta 0	0.410	ΣZ (3.3)	7020
Omega 1	1.55	ΣZ (3.81)	6080
Omega 2	1.34	ΣZ (f)	5319

Optimal structure of the agricultural system

At optimization, we tried to concentrate areas of grassland into one structure with a part of arable land, and for lower-lying areas we considered a self-contained structure with only arable land – and perennial fodder crops without grassland as carbon-source crops. We pursued the division of the system and tried to create conditions for farming subjects either with grassland or without it, considering possible cooperation. Calculation of the optimal structure showed that it is more advantageous to let the system as a whole, with grassland being in a key position. The optimal structure of the whole system with grassland is shown in Table 2.

Table 2: Optimal structure of the agricultural system in the microregion

Crop	P ha	P % P_{or}	P % P_z	Y_s t.ha^{-1}	ΣY_s t	ΣC_k t
S_0 – annual fodder crops	620	10.76	8.33	5.98	3709	1120
S_1 – perennial fodder crops	1036	17.99	13.92	6.73	6972	2105
S_{ri} – rhizomes					6972	1505
S_{2z} – cereals – grain	3534	61.37	47.49	3.43	12123	788
S_{2sl} – cereals - straw					15403	5926
S_n – the other crops	568	9.88	7.63			
S_4 – grassland	1683		22.62	3.9	6564	1982
Total (P_{or})	5758	100.0				
Total (P_z)	7441		100.0		51743	13426

Parameters:

Parameter		Parameter	
Eta 0	0.274	ΣZ (3.3)	5225
Omega 1	1.00	ΣZ (3.81)	4526
Omega 2	1.04	ΣZ (f)	5319

Evaluation:

In the first approach, 568 ha arable land (9.88 %) was released by optimization, which allows the inclusion of an energetic crop – rape, and to close the system in the 2-nd grade. Excessive acreage of cereals (60 %) will be covered with grassland in the system.

Energy balance of the optimized system

It is evident from the presented analyses, that optimization released a part of land for energetic crops. The system can be closed in the first grade by transformation of wastes to biogas. The released acreage enables the second grade of closing. Later on, a part of cereals grain produced can be used for ethanol production, and allows us to close the system in the third grade. The energetic balance of the optimized systems thus depends on cattle stock (in the first grade), acreage released for an energetic crop (second grade), and later on, on the possibility of earmarking a part of production for producing ethanol as a fuel in the system (third grade).

Energetic balance in the first grade of closing:

Cattle stock **ΣZ 4526**

	Biogas production (m^3)	Energy (kWh)	Approximate equivalent in black coal (t)
daily	4 268	7 213	2.86
annual	1 557 826	2 632 745	1 043.7

Energetic balance in the second grade of closing:

Acreage 568 ha

Oil production (t)	Energy (kWh)	Approximate equivalent in black coal (t)
545.3	1 374 156	545.3

Total energetic balance in the second grade of closing the system:

2 632 745 kWh from biogas + 1 374 156 kWh from rape oil = **4 006 901 kWh**

Calculation of energy demand for a distillery

The solution of the energetic problems of agricultural systems unambiguously points out the necessity of cooperation or connection with a processing branch. We have shown that, in the analyzed system, more than 4 million kWh of inner energy can be gained. In principle, the point is to produce more energy than is consumed. That is why we assume the use of primary energy of the system (biogas) o fuel a distillery. The aim was to produce a sufficient quantity of ethanol to produce 865 606 kWh of energy.

Let us suppose, for production of ethanol, we use rye *(Secale cereale L.)* with 57 % starch content, and thus 1 t grain yields 342 litre of ethanol. We assume an average quality of work of distillery. 1 kg ethanol gives 3.38 kWh, and, if we do not consider contraction, than 1 kg ethanol = 1.13 liter.

At daily production capacity of a distillery of 1000 litre, the distillery with machinery consumes 1011 kg black coal (or 2148 kg brown coal). Supposing, the distillery should produce 289 388 litre ethanol and process 846 t of rye, a campaign would last 289 days. Though campaigns are shorter, we choose this time for this case. As 1 kg black coal presents 1.5 m^3 biogas, then demand of coal for covering the campaign is 292 197 t, which presents 438 268 m^3 biogas. As 1 Z (DJ) presents 344 m^3 biogas yearly, then the needed quantity of 438 268 m^3 biogas demands 1 274 Z yearly. But the distillery works only 289 days and not 365, then, for this time, a higher biogas input, and thus higher concentration of animals, will be necessary. Then, 1516 m^3 biogas daily means 1608 Z. For the time of a campaign processing 846 t rye to ethanol requires 1608 Z . As we have shown, the cattle stock in the analyzed system is much higher, but, as we are going to show later, transformation of gas to ethanol has its limitations. By the presented solution, we wanted to point out the great possibilities of energetically closed system, although a rational solution from the aspect of C-balance modifies these possibilities to a certain extent.

The calculation of the structure of an agricultural system for a distillery – 1608 Z (at theoretic feed ration k_n = 3.81 t . Z^{-1}) is presented in Table 3.

Table 3: Structure of the agricultural system for 1608 cattle units

Crop	P ha	P % P_{or}	Y_s $t.ha^{-1}$	ΣY_s t	ΣC_k t
S_0 – annual fodder crops	221	10.1	5.98	1322	399
S_1 – perennial fodder crops	717	32.85	6.73	4825	1457
S_{ri} – rhizomes				4825	1042
S_{2z} – cereals – grain	1245	57.0	3.43	4270	278
S_{2sl} – cereals - straw				5423	2086
Total	2183	100,0		20665	5262

Parameters:

Parameters	
Eta 0	0.2739
Omega 1	1.23
Omega 2	1.17
ΣZ	1608

When we take away ΣC_{ri}, then (5262 - 1042) = 4220 t C remains. This is the amount of carbon taken from soil, which is contained in methane.
The structure of the system leads to higher values of optimization parameters, so to a certain C surplus. The cattle stock is decisive, that is why the other quantities must be subordinated.

We can draw the conclusion, that the demanded energy for a distillery with 289 days long campaign requires 2183 ha of land under the given conditions.

20 665 t dry matter and 5 262 t active C must be produced on this land, from which 4 220 t C will be transformed into CH_4. As the original optimized system can have 4 526 Z (it really had 5 319), then for the work of distillery for the mentioned campaign 35.5 % of the calculated cattle stock is needed.

C-balance compensation

The loss of carbon (C_0, C_1, C_{2z}, C_{2sl}) is 4 220 t, which means 4 220 / 0.3847 = 10 970 t ΣY_s (thus 1.474 $t.ha^{-1}$). Therefore, we would divide this dry matter quantity between crops (the acreage of rape will be unchanged). At the same time, it is necessary to respect the limits of maximum yields, which cannot be exceeded. In the final solution, we used the maximum yields for each crop (annual fodder crops, perennial fodder crops, cereals, and grassland). We reached a nearly accurate C-balance, including covering 110 t of C loss of rape seed. The structure of the agricultural system of the microregion, with good C-balance, is presented in Table 4.

Original optimized system produced volume ΣC	13 426 C
C demand for CH_4 production	4 220 C
C loss of rape seed	110 C
New optimized system after including of rape	17 726 C
Deficit in C-balance	- 30 C

Table 4: Optimized C--balanced structure of the agricultural system of the microregion

Crop	P ha	P % P_{or}	P % P_z	Y_s $t.ha^{-1}$	$Y_{s\,max}$ $t.ha^{-1}$	ΣY_s t	ΣC_k t
S_0 – annual fodder crops	620	10.76	8.33	7.07	7.1	4389	1325
S_1 – perennial fodder crops	1036	17.99	13.92	10.2	10.2	10567	3191
S_{ri} – rhizomes						10567	2282
S_{2z} – cereals – grain	3534	61.37	47.49	4.05	4.06	14347	932
S_{2sl} – cereals - straw						18229	7012
S_4 – grassland	1683		22.61	5.87	5.87	9879	2983
S_{5z} – rape-seed	568	9.88	7.63	3.0	-	1704	110
S_{5sl} – rape-straw						4311	
Total (P_{or})	5758	100					
Total (P_z)	7441		100			67978*	17726*

without rape

Evaluation:

Increase of C-sources has been reflected in parameters:

Eta0	0.215
Omega1	1.23
Omega2	1.17
ΣZ(3.81)	6518
h_Z	0.88

Balance of C is good.

Finally, as an alternative to the optimized C-balanced structure of the agricultural system of the microregion as prtesented in Table 4, we have computed another variant (Table 5). Here, the solution of C-balance means partly the intensification of carbon-source crops (perennial fodder crops, annual fodder crops, and grassland), and partly the increase of their acreage against cereals. In this case, yields (Y_{s1}, Y_{s0}, Y_{s4}) being 90 % of the maximum yield values were sufficient to achieve a well-balanced structure and compensate for the loss of carbon used for energetic purposes.

Table 5: Alternative optimized C-balanced structure of the agricultural system of the microregion

Crop	P ha	P % P_{or}	P % P_z	Y_s $t.ha^{-1}$	$Y_{s\,max}$ $t.ha^{-1}$	ΣY_s t	ΣC_k t
S_0 – annual fodder crops	755	13.12	10.15	5.98	7.1	4827	1458
S_1 – perennial fodder crops	1440	25	19.35	9.04	10.2	13215	3991
S_{ri} – rhizomes						13215	2854
S_{2z} – cereals – grain	2994	52	40.24	4.05	4.06	12127	788
S_{2sl} – cereals - straw						15401	5925
S_4 – grassland	1683		22.61	5.28	5.87	8886	2684
S_{5z} – rape-seed	568	9.88	7.63	3.0	-	1704	110
S_{5sl} – rape-straw						4311	
Total (P_{or})	5758	100					
Total (P_z)	7441		100			67671*	17700*

* without rape

Parameters:

Eta0	0.218
Omega1	1.64
Omega2	1.39
ΣZ(3.81)	7068
h_Z	0.95

In the case of $\Sigma Z = 6518$ $k_n = 4.13$, which is very realistic.

DISCUSSION

The presented solution is realistic, considering that compensation of C consumption remains within maximum yield values. At the same time, this reality shows that the usage of C to be transformed to methane gives preconditions for the intensification of agricultural production, as it extends the area of consumption of energy – in the presented solution, energy for agrotechnical technologies and transport in agricultural system. Optimization of the agricultural system gives preconditions to release acreage for the use of energetic crops, and thus for the further limitation of input of external energy. In connection with the usage of CH_4 in biogas form to provide energy for driving a distillery, the production of ethanol as a fuel for machinery is secured. The solution of the optimal structure and compensation for the C-balance deficit necessitates, that the system should not be divided, but it must be solved as a whole, whith grassland having a key position. In this sense,

cereals use 61 % of the arable land, which is typical for a mountain and submontane region, where more than 30 % of carbon sources are effective ([5]). In the analyzed system, this is 44.86 % of carbon sources, from which 22.61 % is grassland. This type of system can be classified ed as specialized to "Cattle Breeding and Grain". The "consumer" is a neutral crop (rape), from which just the carbon of seed leaves the system, while straw, after being cut, stays on the field and is mineralizing, and thus practically does not change the C-balance. Parameters of optimization show, that the system can be well balanced in carbon, under the condition, that it will be intensified. The reality, that the grade of closing the system has been quamtified, is an important knowledge. This way, the system becomes more stable and invariant. It has been confirmed that an agricultural system of submontane and mountain regions is a considerable factor for production of renewable energy, and is able to compensate for external energy by its own energy, and substantially influence the economic efficiency of production, and above all, to become an important ecological factor.

For a clearer image of using the inner energy of the system, we have counted individual parts of its use. We assume that all gained biogas will be used for ethanol production, that is, the whole of 740 673 kWh will be used in the distillery season. Further 1 374 156 kWh from oil and 865 270 kWh from ethanol, thus 2 239 426 kWh in whole, can be used for transport and agricultural technologies. Assuming that the power output of a tractor in average is 100 horsepower = 73.5 kWh, then its demand of energy at eight working hours during 360 working days will be 176 400 kWh yearly. So, this energy provides fuel and lubricants for 13 tractors during the whole year. Provided the gained energy will be used for driving an electric generator of 400 kW power output, then the whole yearly energy demand will be 1 168 000 kWh. Energy from oil and ethanol will provide fuel for two such generators in the agricultural system. Of course, here again, the principle must be accepted, that the energy will be used only for the system, and must not be dispersed in other areas outside the system.

The optimized system with limiting parameters gives daily biogas production of 4 479 m^3, which is 1 634 926 m^3 a year. Thus, using this energy for driving a generator, the system will be able to provide fuel for the whole-year's work of such a generator and substitute 1 095 t bituminous coal. All the presented examples suggest possibilities, which could be reasonable solutions for the tense economic problems in agriculture, especially in mountain and submontane regions.

The solution of a closed agricultural system allows the utilisation of a part of the acreage for energy production. This energy is partky used in the agricultural system itself, and limits the input of external energy. Thus, the costs of external energy entering the system will be decreased in consequence of the utilization of waste materials and the production of the system. That is why no decrease of production must come about, but intensification, achieving a certain result, could be profitable.

The solution of the agricultural systems closed on the energy principle will demand concentration of research on these problems, particularly finding technologies of effective and automated gaining of methane, its storing, transport, compression of pure methane and its use for mobile machines.

Further on, it is necessary to access the possibilities of minimum quantity of animals, at which biogas production will be profitable. Results from BDR show, that already 40 animals are sufficient ([10]). It will be necessary to assess the minimization of machinery and building equipment for biogas production. A very urgent problem is:

- a consistent delimitation of arable land and grassland
- establish a connection of individual farming subjects for biogas production
- eventually, creating new gas systems, which would provide gas for a certain number of agricultural systems in microregion.

Of no little importance, it is necessary to pay attention to the economic aspects of these technologies of closed systems. There is a question, whether it would not be effective to support the rise of these establishments.

The usefulness of the energetic approach to processes in agricultural systems is emphasized by POSPIŠIL and VILČEK ([7]). They also give coefficients and indices for counting the energetic balance in agricultural systems. Input of energy in crop production, quantification of output energy from crop production, flow and transformation of energy in the subsystem of animal husbandry, as well as transformation of energy in the subsystem of the soil are the main parts of a complex work of ČISLÁK ([2]).

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