THE MAXIMUM TECHNOLOGICAL ENERGY INPUT PRINCIPLE IN THE PLANT PRODUCTION

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Abstract

It is important to mention the fact, that we can cultivate only the 3-4% of the surface of the Earth, and on the major part of these areas the cultivation is not intensive. Hungary is in a special situation, namely on 50% of its territory is cultivated intensively, and 20% of Hungary is covered by forest treated by a nearly intensive way.

The agro-ecology, like the natural, intact ecological system, is a complex adaptive system. It is not true in general sense, as complexity does not mean such diversity that characterizes natural ecological systems. On the other hand the adaptive feature also does not realize, because the breeding emphasizing some characteristics of the given species, decreases the adaptation ability. These changes cause thermodynamic consequences too. In terms of thermodynamics the change of the entropy of the agro-ecological systems evokes: 1. irreversible changes in the plants and the soil; 2. entropy exchange between the system and its surroundings.

In the developed countries large parts of the biological and ecological systems are under anthropogenic pressure that is why it is called agro-ecology. The reason for this is that due to technological energy input the energy output is increasing, thus the utilization of solar energy is also better. The study analyses the efficiency of the different energy inputs (direct and indirect) in the plant production, and introduces the basic elements of the Maximum Technological Energy Input Principle. The MTEIP is a tool for the realization of optimal energy input taking also the ecological aspects into account.

Keywords

plant production, thermodynamic approach, energy balance, Maximum Technological Energy Input Principle

Introduction

Odum and Pinkerton (1955) states that free energy production of open systems can be increased in such a way that the entropy of the system is decreasing. The difference between an abandoned and an agricultural ecological system is shown by the entropy content. Entropy equals diversity. In the agro-ecological systems the diversity is declined by eliminating the competitors (weeds, insects, pests, pathogens etc.), minimizing their activities, respectively. By means of these we help the crops to increase the free energy production, which contributes to survival also. The „order making" causes a gradient increase at the same time. It means that through these, the resistance of the eliminated organisms enhances, since the ecological system is programmed for survival, and to diminish the gradient intending to achieve equilibrium and at the same time the highest entropy. From the several examples let us mention only one: the action of insecticides is 10-500 times higher than the action of DDT, in spite of this the harm caused by pests is increasing (Förstner, 1990).

The entropy of natural ecological systems (the disorder and diversity of characterized species) is at the highest level at the given circumstances, while the entropy of agro-ecological system is decreasing after anthropogenic intruding (order). The compensation or the maintenance of this state requires large energy input: technological (technical and intellectual).

The question is how this difference can be expressed by thermodynamic tools. The technological (anthropogenic) energy input decreases the diversity (entropy) of the system, therefore decreases the probability that the abandoned system itself reaches this state. If under the given natural circumstances diversity of flora and fauna is taken as one unit then its change (decreasing) by given technology can be measured and calculated as following:

$$S = -\sum_{i=1}^{F} p_i \ln p_i \qquad (1)$$

where the pi =ni /N; ni is he number of individuals in species i; F is the number of species; N is the total number of all individuals; pi the relative abundance of each species; calculated as the proportion of individuals of a given species to the total number of individuals in the community.

It is undisputable that the base of this approach is the study published by Shannon (1948). According to Shannon's research activity the information theory, the entropy – on physical phenomena originally developed by Boltzmann –, and the entropy of ecological systems harmonize.

The more sophisticated a system is, the farther it moves away from equilibrium. The ordered, complicated structures – with much lower entropy than the simple ones – produce entropy more effectively. The situation is the same in agro-ecology: with the technological energy input the higher solar energy transfer is provided. The question is: where is the limit of „order making", because this drastic intervention causes harmful ecological consequences. It is also questionable where the limit is of technological energy input providing maximum energy output and input difference.

It is complicated to answer the above mentioned questions, because that means the integration of referring knowledge of several fields of sciences.

„There is other road." (Carson, 1962), namely the biological protection, the physical one (e.g. ultrasound), rotation of crops, mechanical weed control etc.

Methods

As above mentioned in the developed countries the biological and ecological systems are under anthropogenic pressure that is why it is called agro-ecology. Under the conditions of intensive production the bio-energy output should be Eout,techn.. In this case the change of entropy is:

$$\partial_e^{techn.} S = \frac{1}{T}(E_{in,techn.} + E_{out,techn.}) \qquad (2)$$

where Ein,techn. is the energy content of the direct energy sources (diesel oil, natural gas etc.) and the indirect energy sources (fertilizers, other chemicals, production of machinery etc.). (The later is the energy consumption utilized for the production of the given goods.) This energy helps plants to bond the carbon more effectively. As regards technologies of plant cultivation the function of energy output:

$$E_{out,techn.}(E_{in,techn}, E_s) \approx (\partial E_{out,techn.} / \partial M_{in,tech.}) M_{in,techn.} \qquad (3)$$

where E_s is the solar energy that can be taken constant, assuming that the $E_{in,techn}$ is a linear function of mass of used energy source ($M_{in,techn}$).

The efficiency of technological energy input is: $e_r = E_{out,techn}/E_{in,techn}$ the so called energy rate function. Although

this function cannot be made optimal as regards technological energy input, because this is a continuously decreasing function. It is more obvious if we use the function of technological net energy difference (biomass energy-technological energy input), later indicated as Enet,techn (Neményi, 1983).

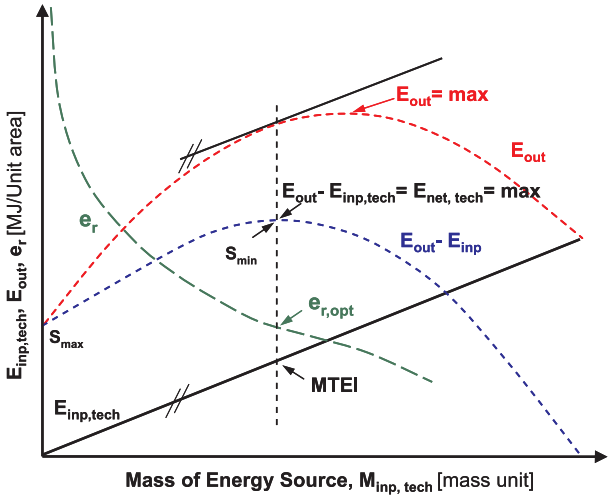

Figure 1. Theoretical approach of demonstration of maximal energy usage and the MTEIP (Neményi, 1983)

The $E_{in,techn}$ function describes the energy content of direct and indirect energy sources. The $E_{net,techn.}$ function (it can be usually described by a parabola) has a maximum at $\partial E_{net,techn.}/\partial M_{inp,techn.}=0$ (Fig 1.). By these differential equations the Maximum Technological Energy Input can be calculated. This gives the highest difference between the biological energy output and the technological energy input. Consequently higher technological energy input decreases the net utility of solar energy: $E_{out,techn}$-$E_{inp,techn}$ is decreasing.

We have to emphasize that the maximum of $E_{net,techn.}$ function is not detectable at the maximum of technological energy input of the $E_{out,techn.}$ function, but at a lower rate, $E_{inp,techn.}$. This rate can be viewed as the optimal energy efficiency: $e_{r,opt}$.

Case studies

Maximum Technological Energy Input

Fertilizing

Maximum Technological Energy Input at the different indirect energy input was calculated. According to wheat experiments for several decades Pepó (2004) described the relation between the

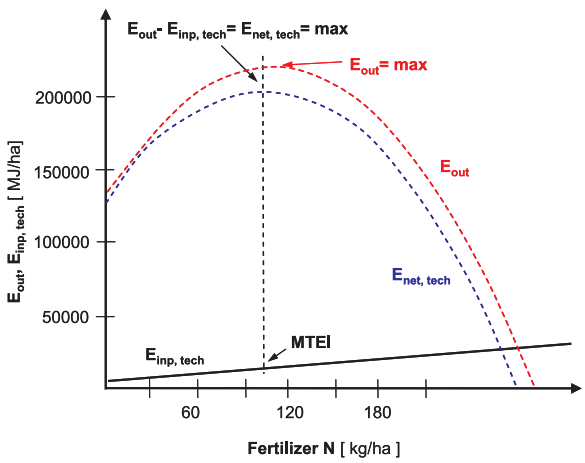

Figure 2. Efficiency of wheat production fertilizing (Data source: Pepó, 2004)

period of 1985-1996 and 1997-2003. In the previous case the biggest energy difference is 189,145 MJ/ha, that shows 11,604 kg/ha difference in output, while the output difference between 1997 and 2003 is 11,159 kg/ha (Fig. 2.). This can be contrasted with the output that appears on the fields out of crop that means non-cultivated, natural ecological area. In Hungary this value is between 6,000-7,500 kg/ha (Láng in Shirezhev, 2000).

Soil Tillage

The diagram (Fig. 3.) shows that the energy input of the soil tillage influences the yield in a similar way as the fertilizer amounts. According to the data on soil tillage force of Kasap and Coskun (2006) tillage force has similar effect on energy consumption of biomass production as fertilizer application.

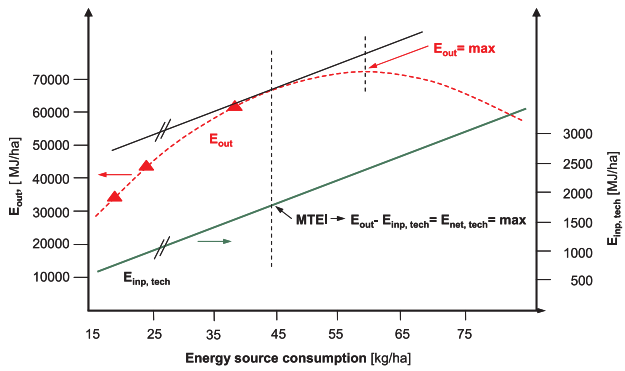

Figure 3. Effect of tillage on energy efficiency for sunflower production (Data source: Kasap and Coskun, 2006)

Conclusions

At the input causing the highest net technological energy, that is the maximum of such input (MTEIP), the rate of the diversity can be defined. On the basis of this information the rate of decreasing entropy can be calculated under reasonable intervention. It is another question who decides the rate between the two extreme energy inputs – taking energy and food supply, social, political etc. aspects into consideration. The effects of technological energy input causing decreasing diversity is gradually decreasing by using rapidly developing technologies of precision plant production and other techniques aided by satellites (Neményi et al., 2006; Neményi et al., 2008; Németh et al., 2007, Milics et al. 2008, Morschhauser and Milics, 2009). Applying the MTEIP contributes to the increase of the utilization of biomass potential in a sustainable way.

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